SMALL ENGINES AND BOILERS

E. P. WATSON

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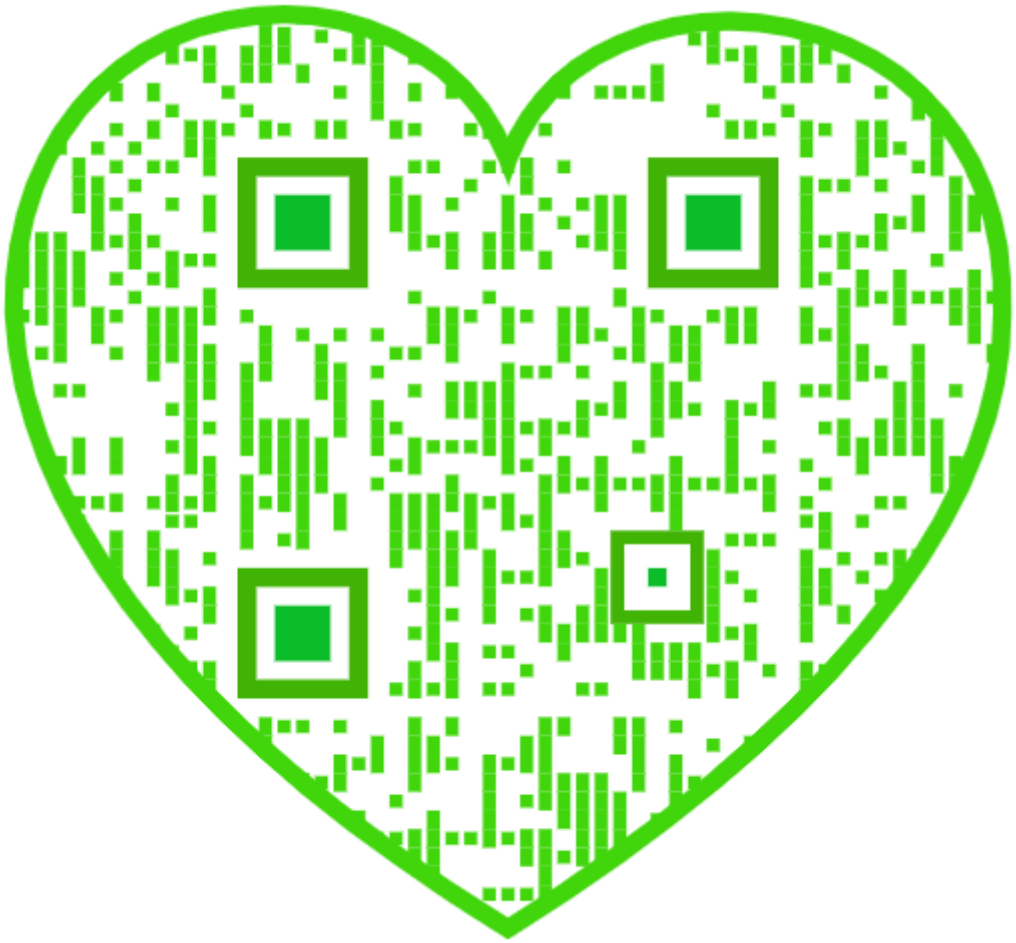

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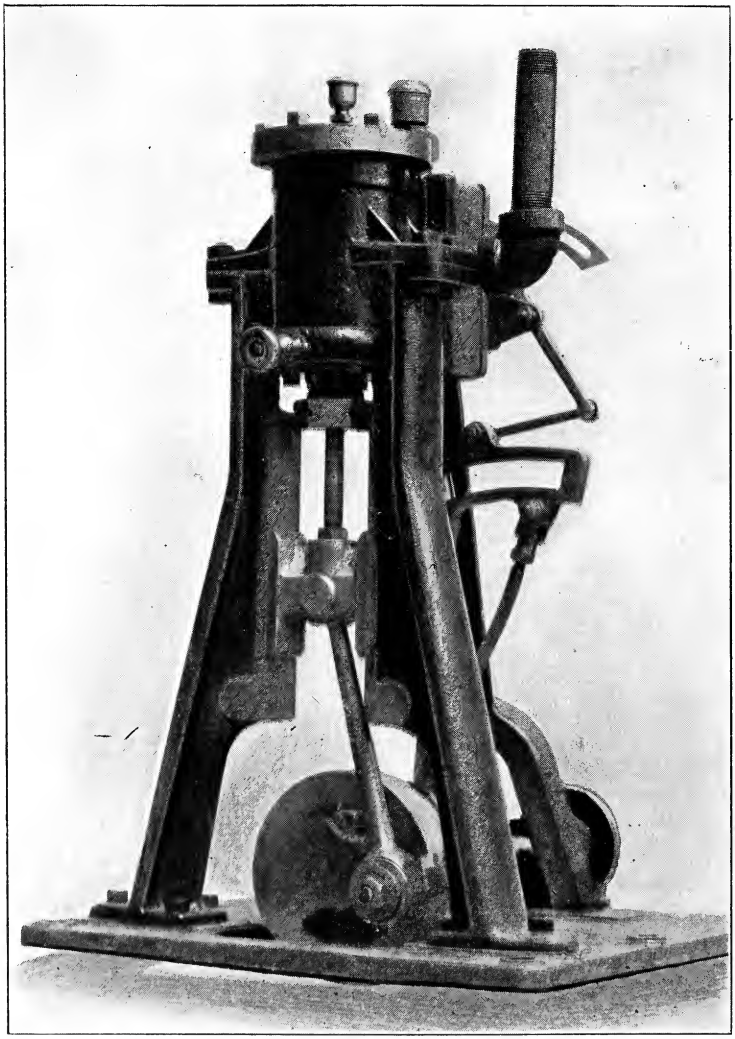

VERTICAL ENGINE OF FIVE HORSE-POWER.

SMALL ENGINES AND BOILERS

A MANUAL

OF

CONCISE AND SPECIFIC DIRECTIONS FOR THE CONSTRUCTION OF SMALL STEAM ENGINES AND BOILERS OF MODERN TYPES,

FROM FIVE HORSE POWER DOWN TO MODEL SIZES,

FOR

AMATEURS AND OTHERS INTERESTED IN SUCH WORK.

BY

EGBERT P. WATSON.

Late Editor and Proprietor of The Engineer.

AUTHOR OF "MODERN PRACTICE," "MANUAL OF THE HAND LATHE," "HOW TO RUN ENGINES AND BOILERS," "THE PROFESSOR IN THE MACHINE SHOP," ETC., ETC.

Illustrated by 30 Full Page Working Dimensioned Drawings.

NEW YORK
D. VAN NOSTRAND COMPANY.
1899

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PREFACE.

THE intention of the author in writing this work has been to furnish specific directions and correct dimensioned plans for small engines and boilers, used either for pleasure or power purposes, in lieu of sketches and gossip about such machines. It has been assumed that those who need a guide of this kind have some acquaintance with ordinary machine work, and the usual facilities for it, if even but a small lathe and a vice-bench; with this outfit a great deal may be done.

The boilers shown will do a great deal of work for their superficial dimensions, if properly managed. They have ample grates and heating surfaces, and will maintain a steady evaporation continuously with good fuel and management. The work also contains hints upon lathe-work, vice-work, and finishing metals, which it is believed

will be of service to those who have had but a limited experience.

High expansion engines have not been treated, for the reason that they are beyond the mechanical and engineering experience of the majority of persons who will purchase a work of this character.

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SMALL ENGINES AND BOILERS

CHAPTER I.

The difference between amateur work of all kinds and that of expert workmen is to be found in its lack of finish, disproportion in sizes, and haste in assembling it. These are common faults; and since they are easily remedied there is no reason why they should not be, if the directions given in this volume are carefully followed.

Lack of finish is sometimes caused by want of the proper agents, files, polishing materials, etc.; but as these are easily obtainable in all parts of the country by mail from the larger cities, there is no excuse for being in want of them; the several mediums employed will be enumerated in the proper place. Disproportion in sizes is easily avoided by considering the work done by the detail to be made and the material employed in its construction, allowing a large margin for safety against accidental strains.

For example: the cylinder of a steam engine is always of cast-iron, or, in model engines, it is sometimes of brass to avoid rusting when idle

and to impart elegance of appearance; it does not require to be of great thickness, even for very high pressures. I have seen steam fire-engines worked at 200 pounds per square inch having 6-inch cylinders only $\frac{1}{2}$ of 1 inch thick; the heads being of the same thickness. No accident ever occurred to them. The same cylinder in a stationary engine would be 1 inch, or $\frac{3}{4}$ of 1 inch, thick to allow for re-boring; but the first-mentioned cylinder was entirely within the limits of safety. In model engines it is quite common to make a cylinder of 2 inches diameter $\frac{1}{4}$ of an inch thick, for the assumed reason that it is easier to make a sound casting of the proper temper for machining than one that is lighter. These considerations hold good in practice, but there is nothing to prevent such a cylinder being bored out so as to leave it only $\frac{3}{16}$ of an inch thick; the result being that the machine as a whole is lighter and not impaired as to its duty.

Haste in assembling or putting machines together is inexcusable for an amateur, who is supposed to have plenty of time at his command; and it arises from a desire to see how the machine will look when it is put together, but, as a consequence, it looks badly. Parts are shoved together anyhow, in line or out of line, and hastily connected before they are half finished, so that an expert workman can tell at a glance that a 'prentice hand did the work.

I have alluded to these common errors in ama-

teur work for the reason that it is requisite to know what not to do as well as what must be done in order to get out a creditable piece of work; and surely if a thing is worth doing at all it is worth doing well.

Of all things amateurs should avoid makeshift methods, such as soft soldering parts together that should be bolted and screwed fast, or using bent wires or parts not turned true where it is necessary to use connections. Soldering is a tinker's job, and belongs to pots and pans, not to machine-work with any pretence to accuracy and durability. We can make an alleged steam engine out of sheet-brass and tin soldered together with wires for connections; but the time spent upon such work is wasted, for the job complete is not worth a moment's notice. It will not stand any pressure at all or do any work, whereas, if the amateur follows the instructions in this book, he will have an engine and a boiler that will do a good deal of work, even to driving quite a number of tools, or a boat 20 feet long, which will carry a dozen people. Such an engine would seem to be outside the pale of amateur work, but this is not the case; for it weighs complete but 90 pounds, and no detail is beyond the capacity of a lathe that will swing 6 inches over the ways and take 24 inches between centres. Complete figured drawings appear farther on for this engine, as also the way to make a drawing for any engine or machine.

CHAPTER II.

DRAWINGS.

An amateur should never make any machine without a drawing of some kind, showing all the connections, the lengths of them, and where they come or are attached. For want of this very necessary preliminary he may find that he has to either rebuild or else cut away parts that interfere, not only doing the work twice over, but making a botched job after all; for any work that is not designed properly on the start never comes right at the end — if it ever has an end.

It is not necessary to show every bolt and nut in such a drawing; but it is necessary to show every connection, the frame, and the lengths and widths of the steam gear, such as the valve and valve chest, the ports, eccentrics, and rocker arms, if any are used, pillow-blocks and shaft, crank and fly wheel, etc. When this is done the amateur can go ahead, secure in the knowledge that he will have a good job if the work is properly executed, and that he will not have to do any of the work twice. Such drawings are called skeleton drawings, and are used in some of the largest shops in the country. Fig. 1 shows such a draw-

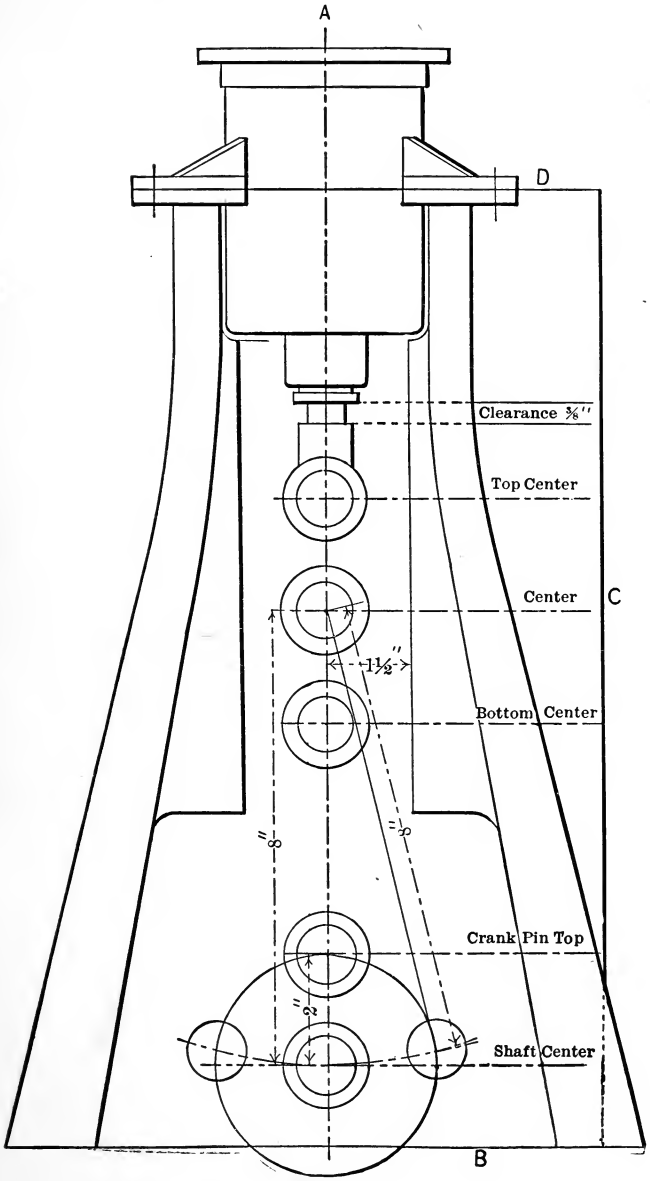

A
D
Clearance ⅜"
Top Center
Center
C
1½"
Bottom Center
Crank Pin Top
Shaft Center
B

Fig. 1.

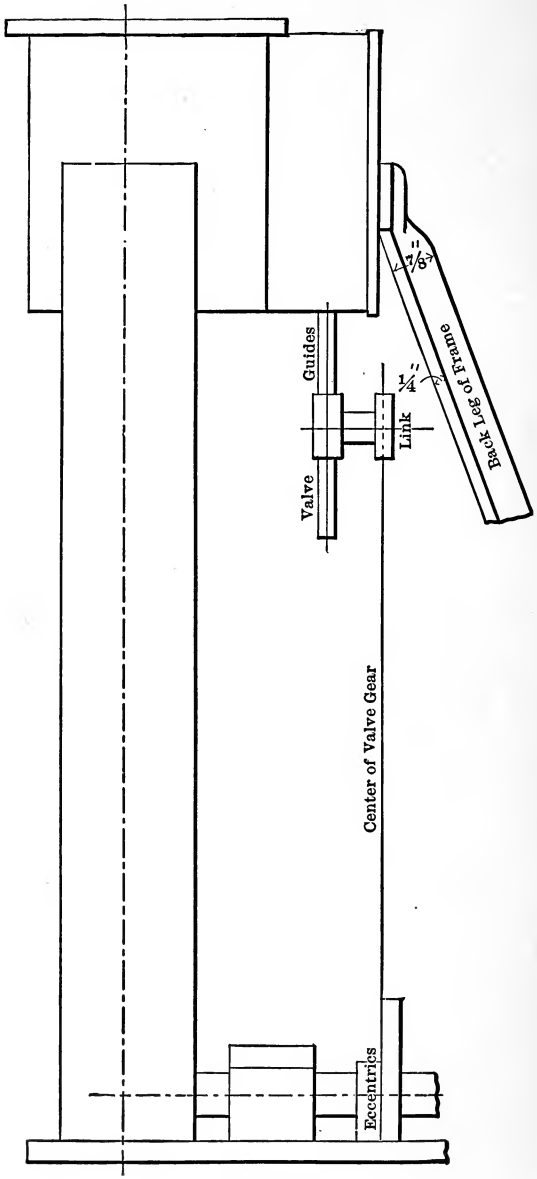

Guides
Valve
Link
Back Leg of Frame
Center of Valve Gear
Eccentrics

Fig. 2.

ing in its incipiency. The first thing is to draw the centre and base lines. Suppose we mean to make a vertical engine of any size — 2-inch cylinder by 3- or 4-inch stroke; then we draw the centre line *A*, which shows the centre of the cylinder, and at the bottom the base *B*, which shows the bed-plate *top*. We have, of course, determined previously just what dimensions we intend to use, and figured all the lengths, so that we know what height the engine will be. For example: the cylinder is to have 2-inch bore, by 3-inch stroke, the piston is to be $\frac{3}{4}$ of 1 inch thick, and the steam ports $\frac{1}{4}$ of 1 inch wide, the cylinder-flanges are to be $\frac{3}{16}$ thick each; then the length of the cylinder would be: top flange $\frac{3}{16}$, upper port $\frac{5}{16}$, including piston clearance, piston $\frac{3}{4}$ of 1 inch, and stroke 3 inches; bottom port $\frac{5}{16}$, including clearance, and bottom flange $\frac{3}{16}$; the cylinder top and head is the same thickness as the flanges; and the stuffing-box is 1 inch, including the gland when in its working position. Now add all these together, and we have the net length of the cylinder complete, to wit: $5\frac{1}{4}$ inches over flanges, and $6\frac{1}{4}$ inches over stuffing-box gland screwed home. We mark these several dimensions (not in detail, but in gross as on the skeleton drawing). Whatever clearance is needed between the cross-head and the gland — say half an inch — is then marked, and the length of the cross-head jaws, say 2 inches. Right in the centre of this, we draw a circle for the wrist-

pin so-called; and from that we measure the length of the connecting rod, usually three times the piston stroke, say 9 inches. This also gives the centre of the shaft-bearing or pillow-block when the piston is at half-stroke. Adding these distances we find a certain length over all, to which must again be added the depth of the pillow block, measured from the centre of the shaft to the bottom. This gives the total height of the engine over all, from top of cylinder head to top of bed-plate, but not the height of the frame, for that depends upon what sort of a connection is used to support the cylinder. Suppose a bracket to be cast on the cylinder at *D*, then the height of the frame would be from the under side of the bracket to the top of the bed-plate and is easily arrived at.

This is briefly the method of getting the main lengths, but has nothing to do with the details of the engine itself, and must not be confounded with them or with the drawing, Fig. 1, which is referred to as an example only.

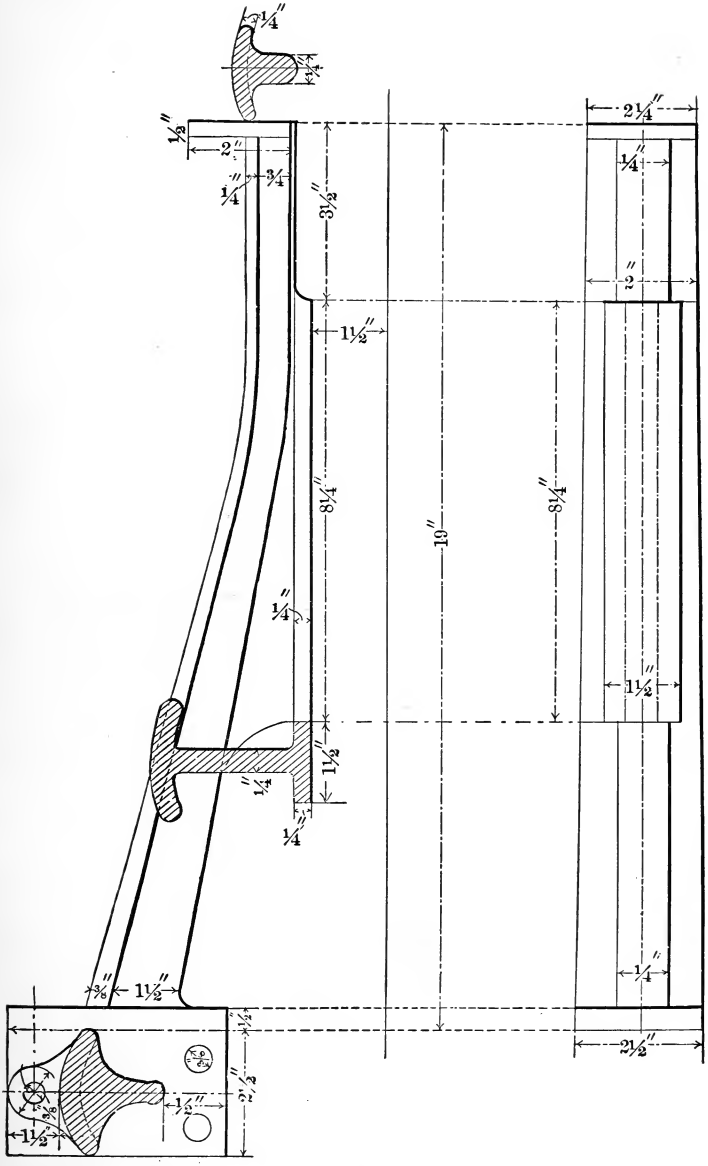


Fig. 3. Frame of Launch Engine, 3″ × 4″.

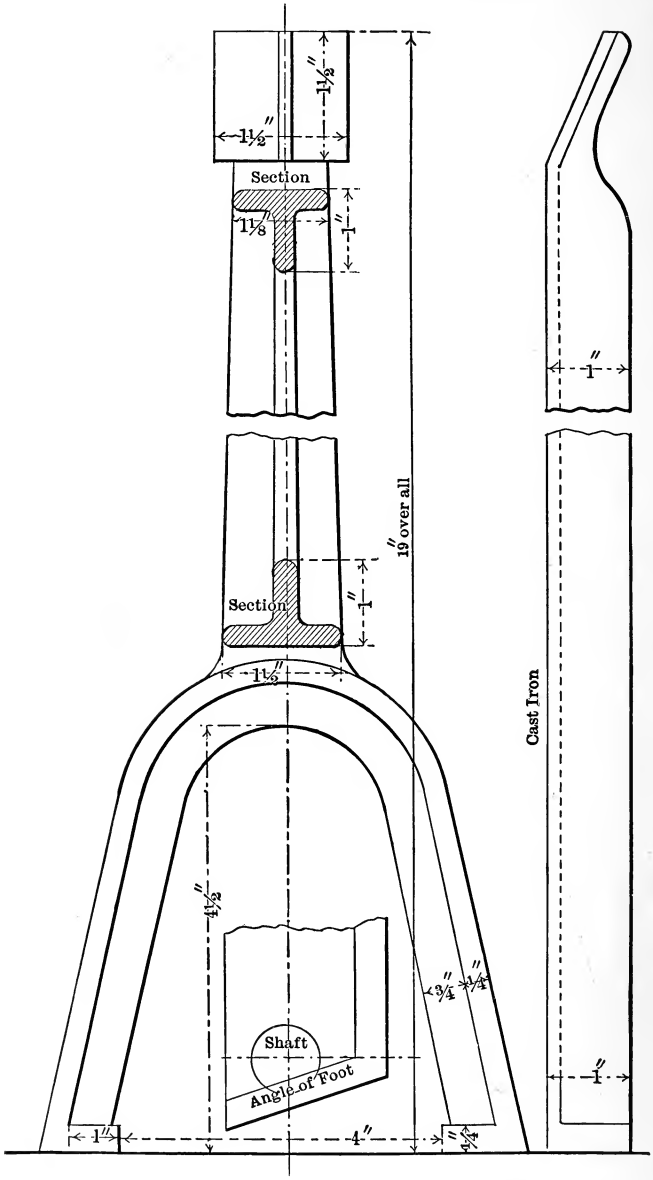


Fig. 4. BACK LEG OF FRAME, 3″ × 4″.

CHAPTER III.

THE plan mentioned having been followed, we are then ready to design details, and the cylinder naturally comes first: it is shown marked finished sizes, Figs. 4*a* and 5, and, as will be seen, is for a model engine of 3-inch cylinder by 4-inch stroke. This engine will easily develop 5-horse power at 800 revolutions per minute, which its short stroke enables it to attain readily. For such speeds the ports must be large and the exhaust free, so as to avoid back pressure on the piston; a suitable boiler for this engine will be shown in the chapters devoted to boilers.

We proceed to draw the cylinder by erecting the centre and base lines as before mentioned; and in this view we need two centre-lines to develop it, as shown in *A* and *B*. The several dimensions alluded to in the second chapter are laid off in their order, and the sizes marked upon them. The bracket *D* is for the head of the frame or cylinder support. The cylinder will require two views, as shown in Fig. 4*a*, and the designer can adopt those shown or make any others for himself.

All other details for this engine are shown in the several figures following. Another style of

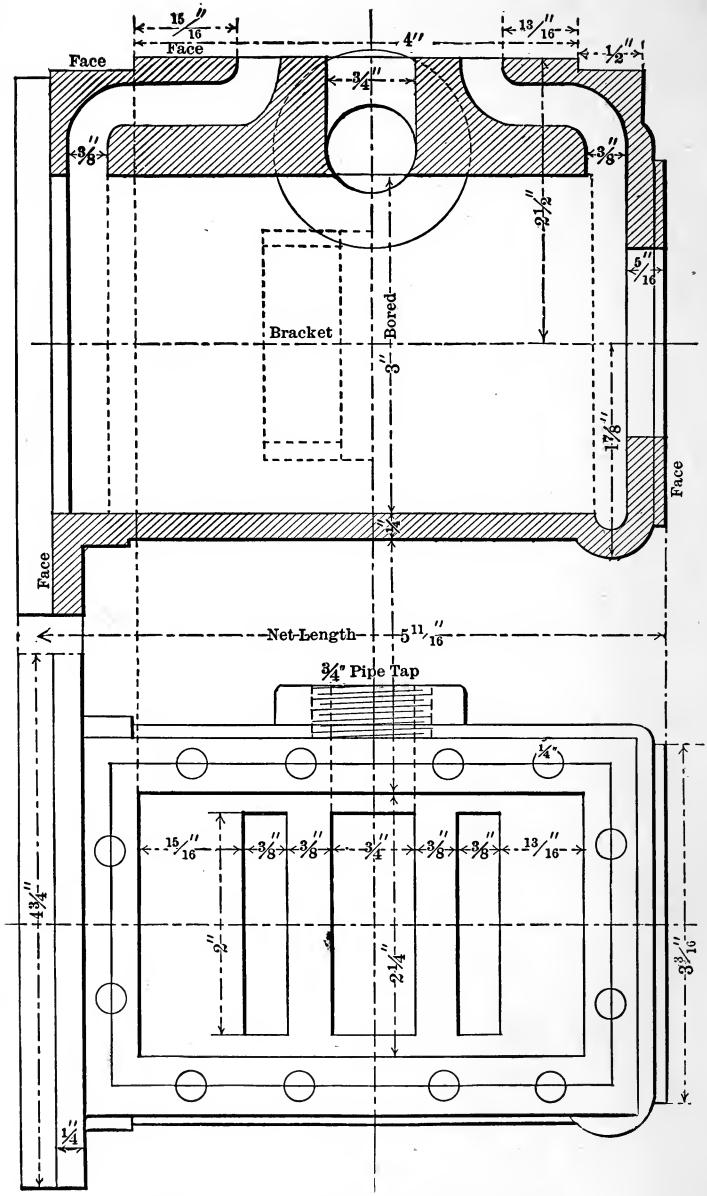


Fig. 4a. CYLINDER–PLAN AND SECTION.

vertical engine which is much simpler and easier to make is shown in the illustration, Fig. 6 This engine is wholly brass, except the columns which are of iron ; even they can be made of brass if preferred. The cylinder of this engine is only ¾ of 1 inch bore, by 1 inch stroke, and weighs

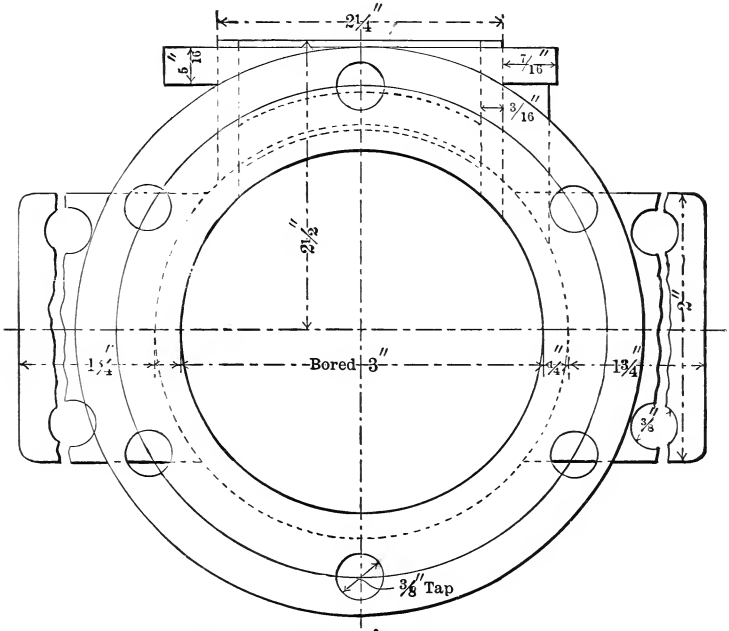


Fig. 5. End View of Cylinder.

but 1 pound. It has, however, driven a small torpedo boat, 4 feet long by 6 inches wide, at the rate of 3 miles per hour with oil fuel under the boiler ; this latter will be shown in the chap-

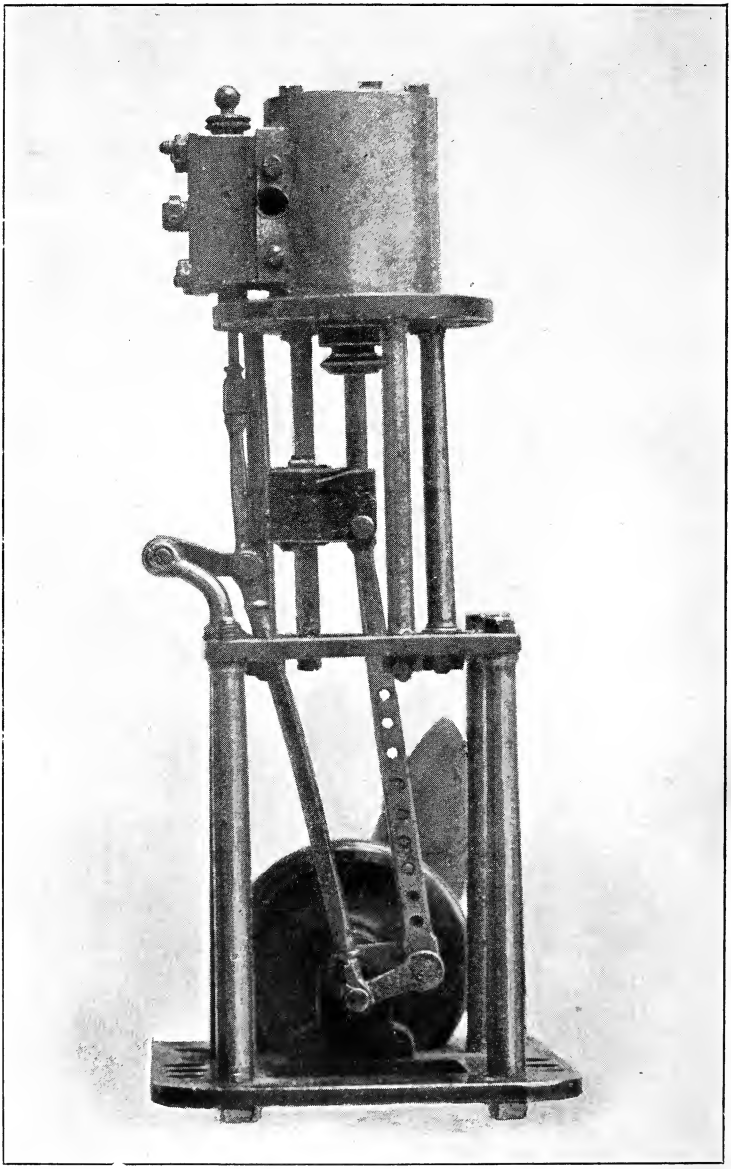


Fig. 6. SMALL VERTICAL ENGINE.

ters devoted to boilers. There are no figured dimensions on this engine, so the maker is left to follow his own ideas in regard to them. As may be seen, the columns are turned all over, and threaded for nuts at each end. The holes in the bed-plate and entablature are no larger than the thread, so that the latter fits tightly in them, and the several plates are made of sheet-brass, highly polished. The screws in the cylinder-head and steam-chest covers have screw-driver heads, and the piston is solid, with no packing whatever; it merely fits the cylinder tightly. The steam-pipe is $\frac{3}{16}$ bore, and the steam-ports are $\frac{1}{16}$ wide by $\frac{3}{8}$ long. The slide valve has $\frac{1}{32}$ lap over the ports, each end, and the exhaust-port is $\frac{1}{8}$ of 1 inch wide. With such minute dimensions as these it is not possible to cast the ports in, so the whole cylinder is cast solid, and bored out in the lathe. The ports are made by drilling in the end of the cylinder at the proper place and on the valve face, and the metal between the holes cut out with a small drift.

It cannot be said of such engines that they are of any particular use; but they serve as studies in small work and close fitting, for as this engine makes some 2,000 revolutions per minute, it must be well made to stand the racket. The entire height of it is 8 inches, and width of base $3\frac{1}{2}$ inches. Horizontal engines are shown, as a type of modern engines, in the plates to follow, which can be made of any dimensions to suit the

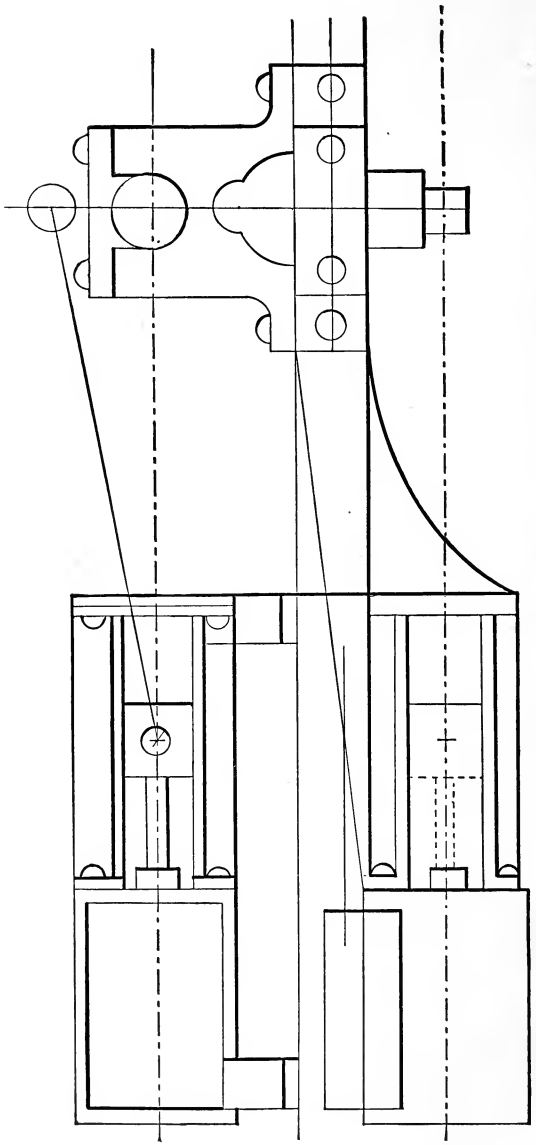


Fig. 7. Horizontal Engine.

views of the maker. The bed-plate is cast in one piece, faced in the lathe on the end where the cylinder is fastened, and has a single eccentric directly connected to the valve-stem without any rocker arm. A good proportion for it is to make the cylinder 1½ inch diameter by 3 inches stroke, ports $\frac{3}{16}$ wide by 1 inch long, exhaust-port $\frac{3}{8}$ wide by 1 inch long, and lap of valve $\frac{1}{8}$ on each end. The eccentric should have $\frac{5}{16}$ throw, have a hole $\frac{1}{2}$ inch diameter for the shaft, and be 1½ inch diameter over all, with a groove, $\frac{3}{8}$ of an inch wide by $\frac{1}{16}$ deep; the straps for the eccentric should be of brass.

A more elaborate plan with figured dimensions is shown on page 61, *et seq.*

CHAPTER IV.

TORPEDO-BOAT engines, so called, are simply vertical engines of the type shown in Fig. 6, being very light and driven at very high speed as to revolutions. There are no other peculiarities about them. They are all steel as to the connections; and the shafts, piston-rods, and connecting-rods are hollow to reduce the weight of them, and, it is needless to say, are built in the very best manner.

Of course there are innumerable other classes of engines in use to some extent, but those shown are the principal ones. Oscillating engines are no longer used for any purpose, except here and there for small pumps or other special work. Neither are vibrating engines, so-called, which have a piston like a door swinging on its hinges, or square cylinder engines, which consist of two rectangular pistons (one inside the other), moving in a square cast-iron box. I do not show these engines; for they are in the nature of freaks, and are of no particular interest when made. Nothing is to be seen externally except square or round cast-iron boxes, without any finish or moving parts. The same is true of the rotary engine. It is merely a more or less com-

plicated wheel (or piston) revolved by steam in a cylindrical case, and takes a lot of steam to run it. That is why it is not in use.

Now having shown several types of modern engines, or those in daily use doing the work of the world, let us look at the methods used to produce them. The drawings are the first thing, and these have been mentioned, but after the drawings come the patterns for the castings. These *can* be made by amateurs with ample time and facilities, but, as a rule, they should not be attempted; for they involve special knowledge as to facility of moulding them, and fine finish to produce smooth castings. Moreover, the patterns for model work are so small that they will cost very little, and it is better in all cases to get them made by regular pattern-makers. A steam-cylinder with cored ports cannot be made by amateurs, and must be got from men skilled in the business. For very small work no patterns are needed, for much of it can be cut out of the solid quite as quickly as from a casting.

The next thing to be considered is the tools to be used, and this is an important matter. It is quite useless to undertake to do good work without the proper tools,—sharp files, reamers, and screw-cutting tools. These last are now made so cheaply, and with such excellent threads and dies, that no amateur should be without a set. Where it can be avoided there is no need of cutting a thread in the lathe, for small rods are very

hard to handle in this way. But a few years ago there was nothing better to be had than a Stubbs's jam-plate, so-called, because it made a thread by pushing or jamming the metal in ridges ahead of it; but the modern screw-sets cut long shavings out of the metal as they advance, and are far better and quicker for amateurs than threads cut with a tool in a lathe.

Lathes themselves vary greatly, and some are not worth the room they occupy. Where money is no object there is no excuse for having a bad lathe; and while they *can* be bought for almost any price (foot-power lathes are alluded to), it is better to get a modern lathe of the Pratt and Whitney, or Gisholt Machine Company's make than a mere trap which never by any chance turns anything the same size for three consecutive inches. Cheap lathes cost about $60, — those with slide rests, so-called, and screw-cutting gear, — but a good reliable tool will cost from $150 to $250; but it is complete in all parts, with many extra fixtures for doing work not belonging to lathes usually, such as milling, gear-cutting, angle-plates for facing, etc., and is well worth the extra cost. Some of the better class of lathes are fitted with small countershafts carried on standards set in the top of the table, so as to drive special cutters or emery wheels for surface grinding. For ambitious amateurs these are the tools to buy; although it is not to be denied that good work can be done on cheap lathes if men are skilful,

and are willing to spend the extra time required. When it is considered that one buys such a tool for a lifetime it is better to have a good one than a bad one.

To dilate further upon the work that it is possible to do in a lathe, we may instance the plane surface of the valve seat of an engine, and any flat surface usually executed in a shaper or planer, or else slowly and laboriously removed by chipping and filing. The cylinder of the engine alluded to is $3\frac{1}{2}$ inches from the centre in its widest part, so it will not swing on what is called a 6-inch lathe; but few lathes are as small as this, and if the owner of one has no better means of doing the work in question, he can raise the head and put half an inch of wood under it, lengthening the belt temporarily. Supposing, however, that the lathe will swing it, the cylinder is chucked on the face-plate, or in any way that will hold it, with the valve seat out; it can then be faced fair and true the the same as any other flat surface. The steam-ports should be filled with strips of wood to keep the tool from gouging or jumping in. The seat for the steam-chest, which is lower than the valve face, can be squared for a short distance so as to indicate the depth, the rest of the metal being removed by filing.

Face-plates are very essential tools, and these can be made in a lathe easily, up to the full diameter that the lathe will swing. Get a couple of cast-iron disks, made as large as are needed, 1 inch

thick. Have them cast the face side down so that they will be without blow-holes, and also have a projection on the back 1 inch deep by 3 inches diameter. This is handy to chuck them in the lathe by, and convenient for use on vice-work. Turn these disks all over to remove the outer skin, and when the working or true face is dressed off rub chalk all over it, and hold a straight edge on it when running slowly in the lathe. This will show at once whether the plate is concave or convex, and the workman must rectify it if needed. Now make another plate in the same way, and having trued both so that they are fair all over, put a little flour emery and oil on the faces and grind them together. This will give dead-true surfaces, and be available for any piece of work that is required to be an exact plane.

The tasks of the amateur are materially lessened and increased accuracy assured by the infinite variety of small tools, gauges, drills, scales, etc., which abound in tool stores, and every one engaged in machine work should have a full outfit of them. It is useless to try to make them with the same accuracy that can be found in those purchased.

CHAPTER V.

THE ENGINE DETAILS.

When getting castings for an engine, don't take them to the nearest foundry that makes any kind of castings, but send them to some concern that makes a specialty of small machine-castings. If a contrary course is pursued one is very likely to get hard iron, full of scabs and with bad faces on them. One concern will make castings for 4 cents per pound while the other will charge 10 or more cents, but the latter is much the cheapest in the end.

Now, suppose we have the castings all in hand and ready for machine, we naturally take the cylinder first because there is a good deal of work to be done on it. Chuck it in the lathe by the flange, and face off the opposite flange. Then take it out, and turn the other flange out and face that. If the cylinder has been well cast, and the pattern properly made, there will be about $\frac{5}{16}$ of an inch to bore out of it. Run one heavy cut through it to within $\frac{1}{16}$ of the proper size, and see if there are any blow-holes in it. If there are, and scabby places besides, caused by the core not being properly vented, condemn the casting at

once. Do not try to fill the holes up with lead or anything else, for it will be sure to come out when steam is let on. A bad casting cannot be made sound with putty. If the surfaces are all correct, try the bore to see if it is parallel. Some lathes bore largest on the outside of a hole and some on the inside or bottom; this is caused by the lathe-head (or spindle) not being true with the ways, and can be easily cured by putting slips of paper on the ways under the lathe-head where it is needed to square it with the ways on the bed. This should be done before the last cut is taken out, and when the bore is verified the last cut needed to bring the cylinder to size should be made. Do not change the position of the tool in any way after taking the cut, but bring it out, and let it run through again on a quicker speed to scrape the surface over. It must be borne in mind that boring a cylinder is a continuous operation. The lathe must not be stopped on a cut in the middle of the cylinder and started again, for that will make a ridge in it.

Having the cylinder properly bored, counterbore it, as shown by the drawing, $\frac{1}{16}$ of an inch below the upper end of the steam-port. Do not make the mistake that some do, and counterbore to the bottom of the steam-port, for that will make the piston leak badly. The piston travels to within $\frac{1}{16}$ of an inch of the cylinder-head, consequently it travels over the port; if the upper end is counterbored to the bottom of the port that

takes away the bearing of the piston at a very important part. The bottom of the cylinder must also be counterbored, and it can easily be done from the front end.

The cylinder-flange must now be turned externally to the right size, and the end of the steam-chest also faced. It will be seen, page 53, the lower head of this cylinder is very small, and where it enters the cylinder is only 1½ inches diameter. This hole must of course be bored at the same time that the cylinder is; for the piston-rod goes through it, and it must be true with the cylinder-bore. While the cylinder is in the chuck, take a boring-tool with a square nose about ¼ of an inch wide, and trim off the edges of the steam-port where it enters the bore.

In all these operations go slow, but go sure. Do not attempt to hurry anything beyond its proper speed. Do not spring the cylinder by screwing it up hard in the chuck-jaws, and be absolutely certain that the chuck is true on its faces, if the work bears on the jaws of the chuck. If the chuck is not true, trouble will be experienced when the engine is put together. The flanges will be out of parallelism, and every job done on the lathe will be wrong and hard to locate as to the cause of the difficulty.

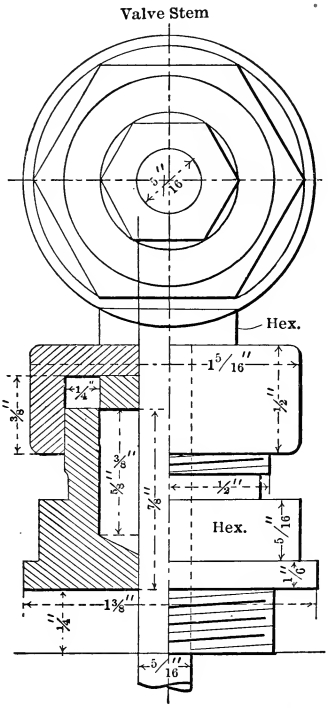
The bracket on the side for the support of the cylinder must be faced off on the bottom side before the cylinder is removed from the chuck after boring; and, as the cylinder cannot be re-

volved completely in the lathe, the belt must be thrown off, and the face-plate revolved, or oscillated, by hand, running the tool in as far as possible, and chipping and scraping the surface true where the lathe-tool does not reach. This detail is important, for if it is not well done the cylinder will not stand square with the guides without a great deal of trouble to make it so.

Now, having the cylinder bored, faced, and turned on its flanges, chuck it so that the valve-face is out, and true that up as explained a few pages back. Possibly the universal chuck will not take the cylinder, owing to the flanges and projections being in the way of the jaws, in which case it must be chucked on the face-plate, and supported by blocks so that it will be firm. If the lathe is large enough a small angle-plate can be put on the face-plate, and a bolt run through the cylinder-bore to hold it.

The exhaust-nozzle must be similarly dealt with, for this has not been cored out by the pattern-maker, but has been left solid. The cylinder must be chucked with the nozzle-end out, and a drill run in as far as it is safe to go, taking care not to run into the cylinder walls. There will then be left a blank end which has to be drilled and chipped out to meet the exhaust-port in the cylinder. This can be done after the cylinder is removed from the lathe. The size of the exhaust-pipe is $\frac{3}{4}$ of an inch inside, and the nozzle must be threaded for the steam fittings of this size. This thread has to be

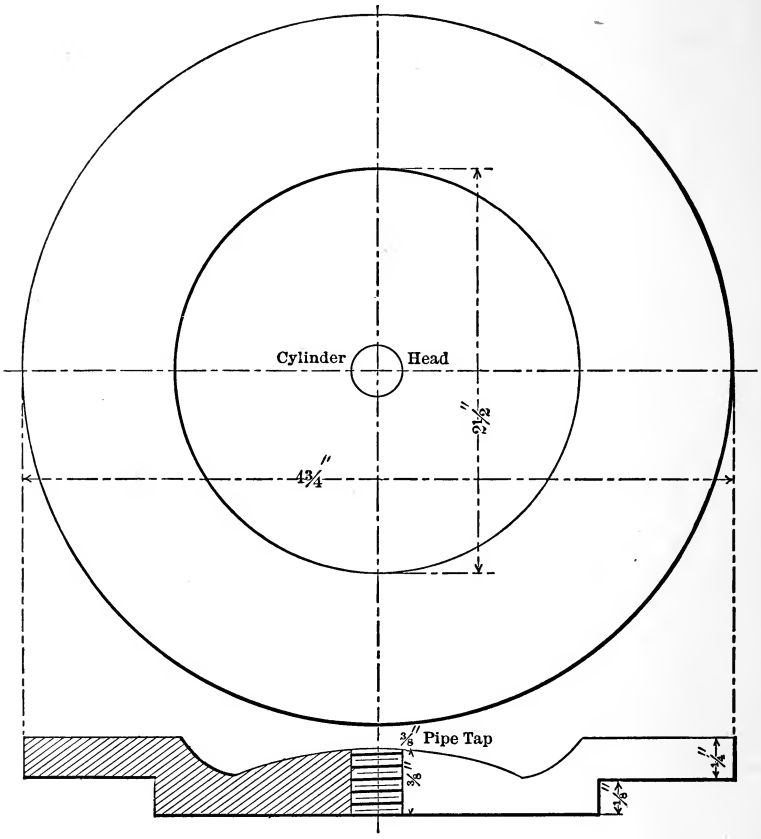
cut in the lathe; a pipe tap will not enter the full size, for the hole is not deep enough. The cylinder-heads are straight-away jobs, as to the upper one, which is common turning. The lower head has the piston-rod running through it, and should be chucked with the stuffing-box in toward the face-plate. The hole for the rod is then bored, and the head faced and turned to fit the hole in the cylinder-bottom. It may then be put on an arbor and threaded for the stuffing-box gland, turned and finished all over, and then, taken off the arbor, re-chucked, and the recess for the packing bored out, truing the head by the outer flange.



The steam-chest can now be put in the lathe and faced off on both sides, and turned on the end. The stuffing-box is screwed into the end of the chest, and is more easily made in that way than if it were cast on solid.

It should be said here, that matters should be so arranged that all the lathe work can be done

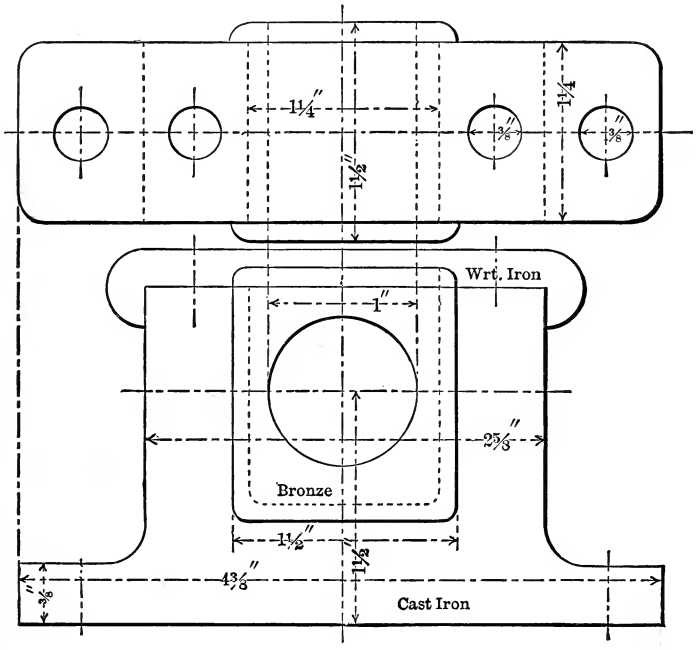
at one time, instead of breaking off and going at the other fittings, if dispatch is any object. The



details will then be ready for fitting and for drilling without unnecessary delay.

In fitting on the heads, and all details where

bolts go through two parts, both pieces should be drilled together. Sometimes clamps have to be employed for this work, in others one or two holes can be drilled first, bolts put in of the right size and screwed up, then the other holes drilled.



In selecting drills for tapped holes, take a drill that will just fill the screw-die without shake, then the thread will be full. For steel it should be a trifle larger than for cast-iron or brass, for the steel is tough, and taps are apt to break if the holes are too small.

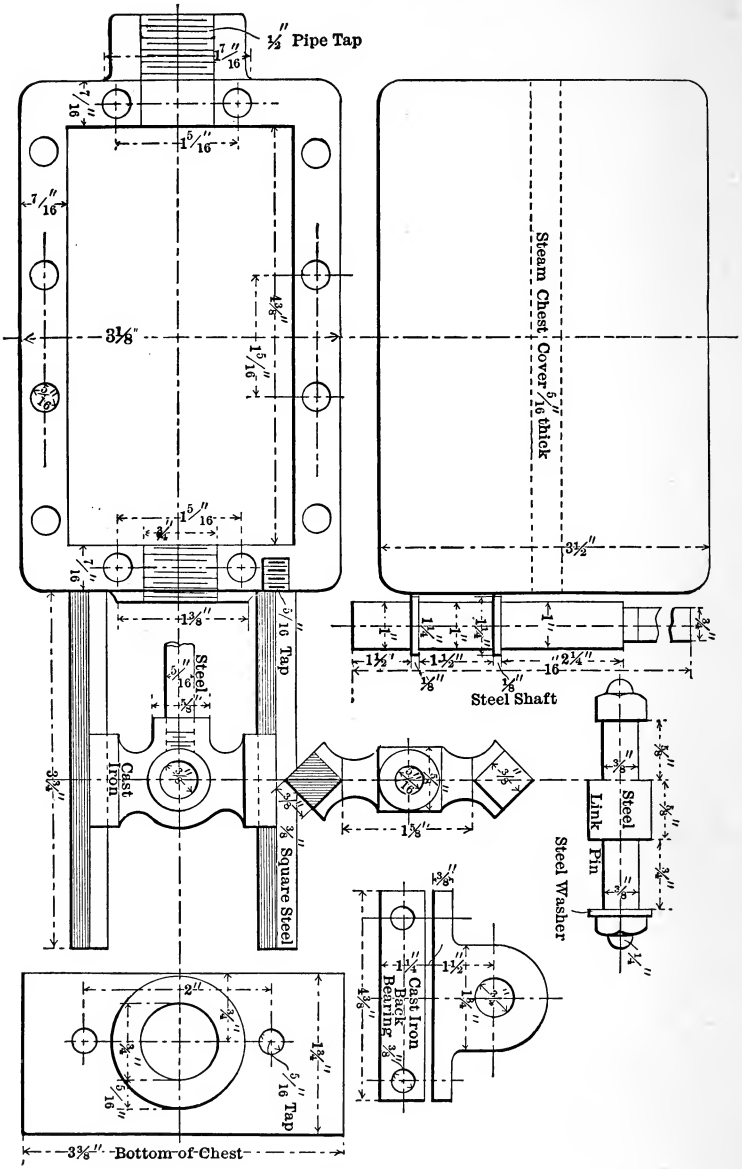

½" Pipe Tap
7/16"
1 5/16"
3⅛"
4⅜"
Steam Chest Cover 5/16" thick
3½"
5/16 Tap
Steel
Cast Iron
⅜" Square Steel
Steel Shaft
1⅛"
Steel
Link Pin
Steel Washer
Cast Iron Back Bearing ⅜"
3⅜" Bottom of Chest

Fig. 8.

In drilling all holes that are blind, that is, are not through holes, look out and not go too far; measure the exact depth of the hole, and make a slight mark on the drill shank as a guide in drilling.

In making bolts for studs that are to be screwed in get "Bessemer rods," so-called, which is very soft machine steel; never use common iron wire for this purpose. Cut all bolts to the right lengths, and round the ends over, holding them in the chuck while cutting the threads on the ends.

It is unnecessary to make hexagon nuts nowadays, as they can be had in tool stores down to $\frac{3}{16}$ of an inch in diameter. Stove bolts for ordinary common work, where parts out of sight are merely held together, can be bought very cheaply, down to $\frac{1}{8}$ of an inch; they come in all shapes nearly, button head and countersink, and are very handy for general work.

This is also true of machine screws, so-called. They come in all sizes, both brass and iron, with heads of all shapes, and fit standard size threads; not always do they fit the taps however.

In the foregoing directions, it is understood that reference is made to the launch engine, Figs. 1, 2, and 3, and apply to it wholly; but in so far as general work or execution of work is concerned they apply to any other engine, or to any other machine which has similar details. It may be remarked also, as a truism, that all machine work under heavy strains, especially where reciprocat-

ing, or vibrating, or high rotary speeds are involved must be "iron and iron," so called, as to contact of parts. No "liners" or false strips of metal of any kind must be interposed, and there must not be any false holes either. Every hole drilled in two parts that are one part in the end must be diametrically opposite the other. Absolute integrity must prevail or the work is worthless when done.

CHAPTER VI.

FURTHER DETAILS.

It will be observed that the frame of the engine is squared top and bottom, and this can be done by chipping and filing; but it is wiser to take it to a machine shop and have it planed, where such facilities exist, for it and the guides must be square with each other.

In this engine, and all small engines in fact, the design must be so arranged as to the machine work that it is certain to be square without lining up. It is impossible to line up small engines of 3-inch bore and under, for the parts are inaccessible, and ordinary eyes cannot see small deviations. Moreover, it is not necessary to use lines; squares, for straight plane surfaces at right angles, are better. If every surface is true, the parts will come together accurately, and the engine will be noiseless in action. As a rule, small engines "pound" like sewing-machines, and make as much noise as type-writers. The reason for this is that they are out of truth all over.

I have been explicit in these directions, perhaps diffuse, for the reason that works purporting to give directions to make small engines abound,

and, as a matter of fact, give no directions at all, or very superficial ones at best. Skilled workmen, of course, know how to do machine work correctly, and are aware of the penalties of doing it incorrectly; but as this work is intended for amateurs who are not supposed to have great experience in all lines, I have thought it better to give full directions to produce good results. Persons who "know it all" do not buy books; it is only those who wish to learn and are willing to learn who profit by them.

To return to the engine work; we have now got our cylinder and its heads out and the steam-chest partly finished, and may turn to the piston and its rod. The latter is made of machine steel and is threaded on both ends; one where it screws into the piston, and one where it screws into the cross-head, with a check nut to keep it from turning next to the latter.

These threads must be cut in the lathe and a tap made with finer threads than the average machine tap for this size hole. The thread should be not less than 20, and need not be over 1 inch long with just enough taper to start it in square. The piston (see page 47), is screwed on the rod and the end of the latter riveted over, a hexagon on the top of the piston being to screw the rod into the cross-head. The piston is a mere disk without packing, and is made as light as possible to keep the engine in balance, for the weight is chiefly on top. No packing should be put in

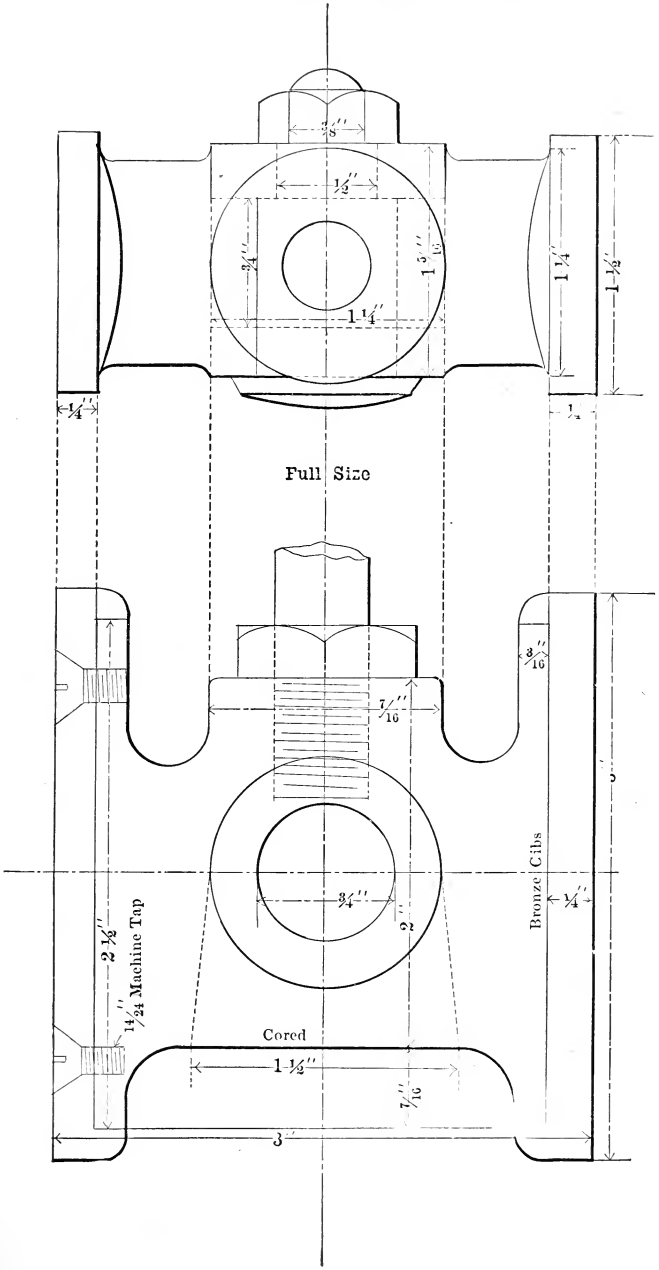

7/8"
1/2"
3/4"
1 3/16"
1 1/4"
1 1/4"
1-1/2"
1/4"
Full Size
3/16"
7/16"
Bronze Gibs
1/4"
3/4"
2"
2 1/2"
1/24 Machine Tap
Cored
1-1/2"
7/16"
3"

Fig. 9.

small pistons, but they should fit the cylinder tightly; the leakage amounts to little or nothing. The piston-rod, and everything else to be turned, must have drilled centres in it, and be cut to the proper length so that the centres will remain, and the piston should be turned all over inside and out. It is of cup form, inverted, which makes a little more clearance on the under side, a matter of no moment.

The cross-head comes next, Fig. 9, and this is made of cast-iron with brass gibs; these last are made fast by counter-sunk machine screws tapped into the cross-head. No adjustment is required for wear, since the surfaces are very large for an engine of the size, but when needed pieces of paper can be placed between the gib and cross-head. It works closely, but freely in the guides, so that there is no lost motion. The cross-head can be wholly made in the lathe, the faces of the jaws being faced parallel by centring them, and putting them between the centres, or by putting the cross-head upon the face-plate; the ends being turned true it is chucked and the hole for the rod drilled and tapped. The wrist-pin hole is then bored, and the job is complete except finishing, and drilling and tapping the holes for the gib-screws; these last should be of brass.

All the pins, cross-head, and crank, and those for the link motion, should be made of steel, and carefully turned to standard sizes to fit reamers or reamed holes.

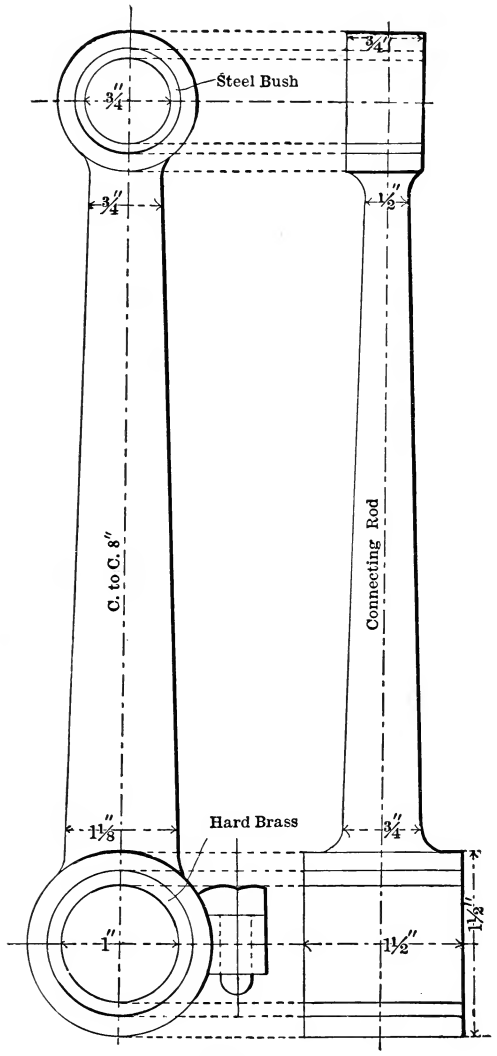


Fig. 10.

The crank-pin should have a $\frac{3}{8}$ hole bored through it to lighten it up, and it must be a driving fit in the crank-eye. When put in the crank-eye is to be heated a little so as to expand it, the pin inserted, and riveted over afterward; the shaft is also of machine steel finished all over.

The connecting-rod is forged of steel in one piece, and has a lug on one side for a binding-screw to take up slight wear. In all high-speed engines everything must be as simple and as solid as possible to avoid their working loose. The crank-pin brass is therefore made in one piece like a bush, driven in to the connecting-rod end and slotted; the distance-piece between the lugs goes through this slot, and the screw holds all fast. The bush is then reamed to size; and the rod is attached by slipping it over the pin, the nut and washer on the end making all secure.

Now, in boring the crank-pin and shaft-holes in the crank itself, the greatest care must be taken to have them absolutely true and square. This is one of the most important jobs about the engine; and if it is not rightly done the engine will never work smoothly, and the error can never be remedied without a new crank. The way to do this job is as follows: —

See that the face-plate is absolutely true before beginning it, and do not allow the least imperfection in truth to exist. Then bore the shaft hole, and face the crank true all over. Then, having laid out its length from centre to centre pre-

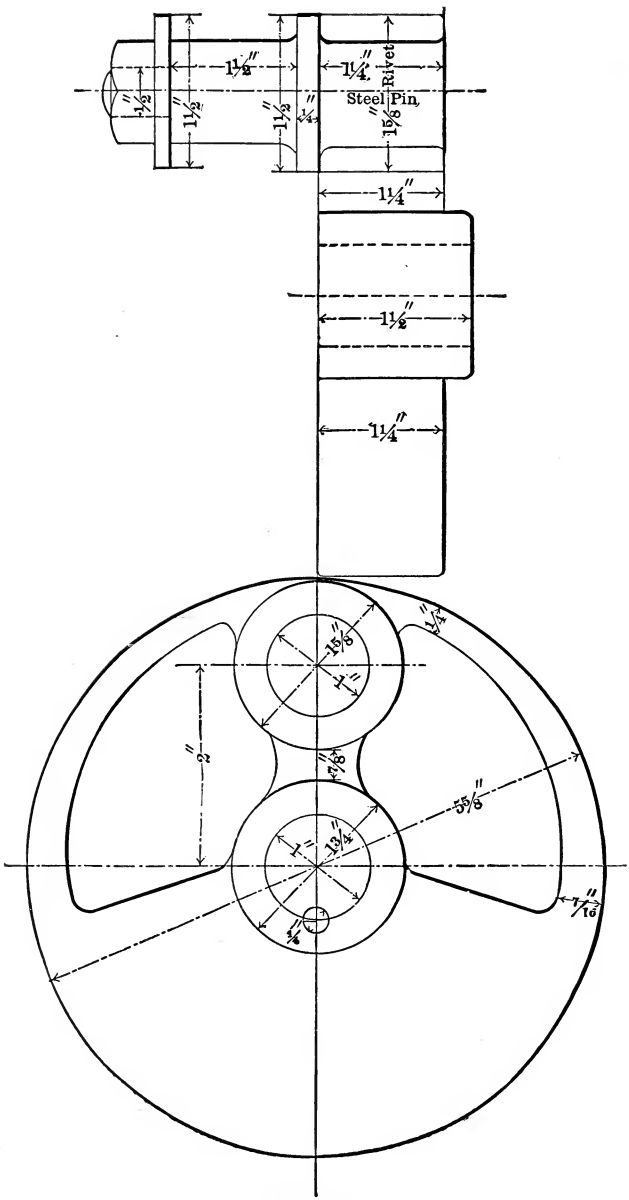
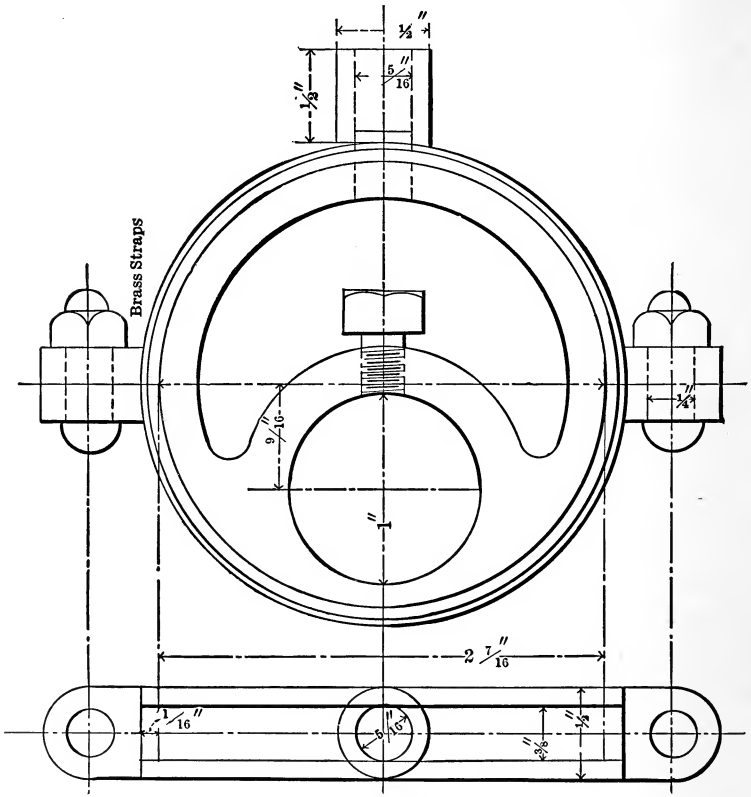


Fig. 11.

viously, reverse the crank and put the face-side next to the face-plate, with the crank-eye in the centre in position to be drilled, being sure that the crank is flat against the face-plate all over.



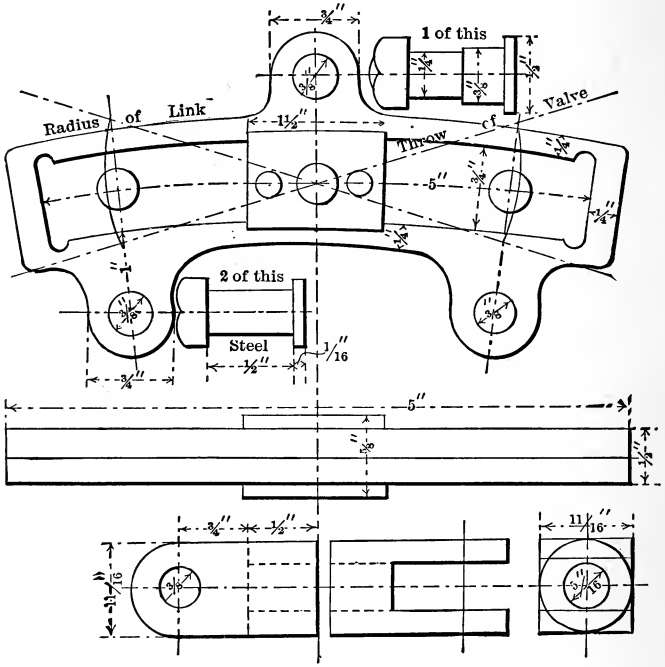
The eccentrics are of cast-iron, and can be all finished in the lathe without any trouble at all. Chuck them true, and face them off both sides, then bore the hole on one side for the shaft.

CHAPTER VII.

We must now consider the link and its connections; and in this job the amateur will have an opportunity to show his ability or the want of it, for it is a very important detail. It must work freely in all parts, and yet have no lost motions; the link-block must bear squarely on both faces of the link, fit closely, and slide easily; the pins in the lugs must be a tight fit without binding, and the whole, though made of many pieces, be as if it was in one piece. The first thing to be done is to face both sides in the lathe to an equal thickness, then lay off the radius or curve of the link to the size marked on the drawing and then the several holes. These, and all other holes drilled, must be standard sizes, and allowance of $\frac{1}{64}$ made for reaming them. After the holes are reamed they must be lapped out, as it is called, in order to obtain a perfect surface; for these bearings have a great deal of work to do.

Lapping is accomplished in this instance by casting a piece of lead 1 inch in diameter and 3 inches long; put it in the chuck, and turn one end to the size of the hole, and about 1 inch long. Then apply oil and the finest flour emery or crocus, and polish the interior as smooth as possible.

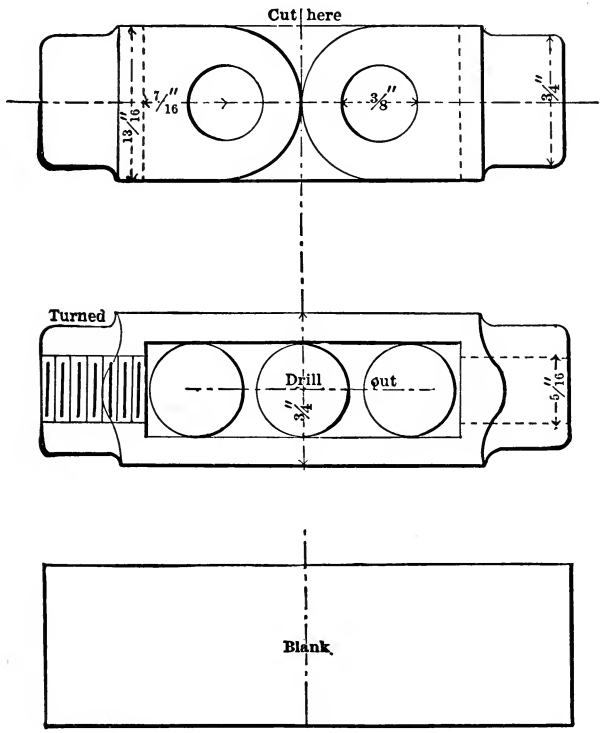
Run the lathe on the highest speed, and keep the work moving back and forth, turning it all the while. When the pins that go in the hole are fitted they should be similarly treated, so that they



will be perfectly smooth and true, and without the least shake in the hole.

It will be observed that there are two wrought-iron jaws on the eccentric-rods that engage with the links; these are too small to forge, and the best way to make them is to get a piece of square

iron forged to size of both jaws, and then drill the slot as shown in the sketch. This makes it handy to turn the ends, and drill the holes for the taps; and both jaws are exactly alike then, the drilled



slot being, of course, cut out square and filed true, the jaws being separated afterward by dividing into two parts.

The link-block should be made of hard brass,

well hammered before tooling to condense it, and it must fit the slot in the link accurately. To do this it will be necessary to use a scraper, for no files can be used on small high places.

In drilling the holes for the steam-chest bolts, great care must be taken also. Drill the chest first, then put it on the cylinder, and drill two holes on opposite ends through the chest-holes in the flange, or steam-chest seat, on the cylinder; tap these holes out, and screw the bolts that belong in them down hard. Then drill the rest of the holes through the chest into the flange; it is only necessary to drill far enough to mark the position of the holes accurately, using a drill the full size of the hole in the chest and afterward substituting the drill for the tap. If this is properly done, every bolt will go in square and true; if it is not properly done, much trouble will be found in getting the bolts in. The cover can be drilled in the same way.

These instructions seem to an expert workman unnecessary; but they are not to amateurs, to whom this book is addressed; it is from the small things, apparently small, that great annoyances and extra work arises if they are not properly executed.

The valve should also be of hard brass; put in the vice, and face it off to the proper length as shown by the drawing, being careful to keep the ends or port faces of the same length from the exhaust-port. Measure this cavity, and see if it is as wide as the inside edges of the ports on the

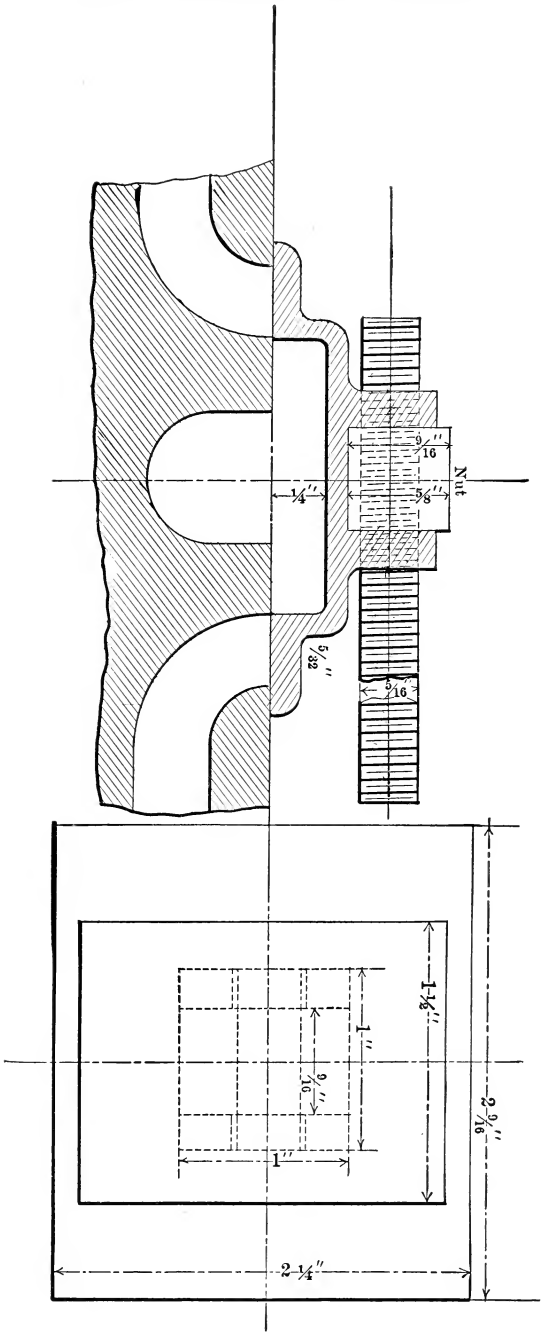


Fig. 12.

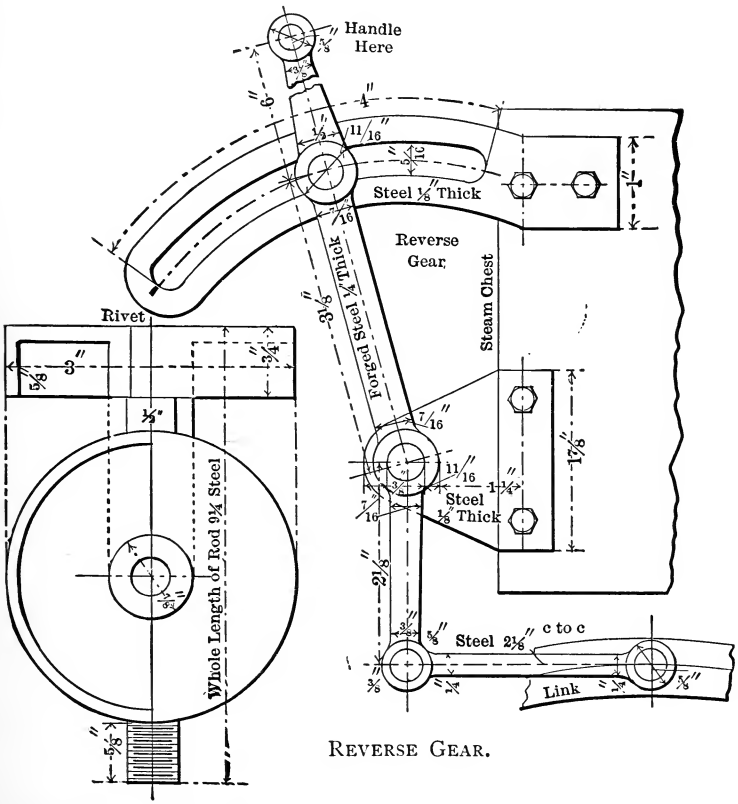
cylinder, as per diagram, having, of course, dressed out the cylinder ports with file and chisel so that they are square and true; then put the valve in the chuck and square the working face true. When this is done try the face-plate on the cylinder and dress it fair, and do the same by the valve, scraping both to an accurate fit. No emery must be used on this job, as it will run down into the ports and be blown into the cylinder when the engine is put to work. The nut on the valve-stem which drives the valve must fit the lugs on the back closely, yet not stiff enough to cock the valve when it is driven back and forth at high speed.

The piston-rod must be carefully turned and threaded for both the cross-head and the piston, and the latter must be screwed on hard to its seat, the rod riveted over, and both put in the centres and finished to size, the rod being draw-filed at the last operation.

Do not make any mistake about this job, such as thinking it will make no difference if the lathe centres run out a little bit. It will make the greatest difference, — a fraction of an inch, a very small one, of error will make parts bind when they are assembled, and it will be hard to discover where the bind is. Absolute truth in work is of the first importance, then there will be no binding; and no fussing with files in the wrong place when assembling.

The shaft should be turned to the proper size

and finished all over, the crank-end being left the thickness of a piece of letter-paper larger than the bore of it. The crank should then be heated



REVERSE GEAR.

slightly, enough to expand it, and the crank slipped on; when it is cold it will be solid in its place, but a quarter-inch hole should be drilled at the junction of the crank and shaft and a steel pin

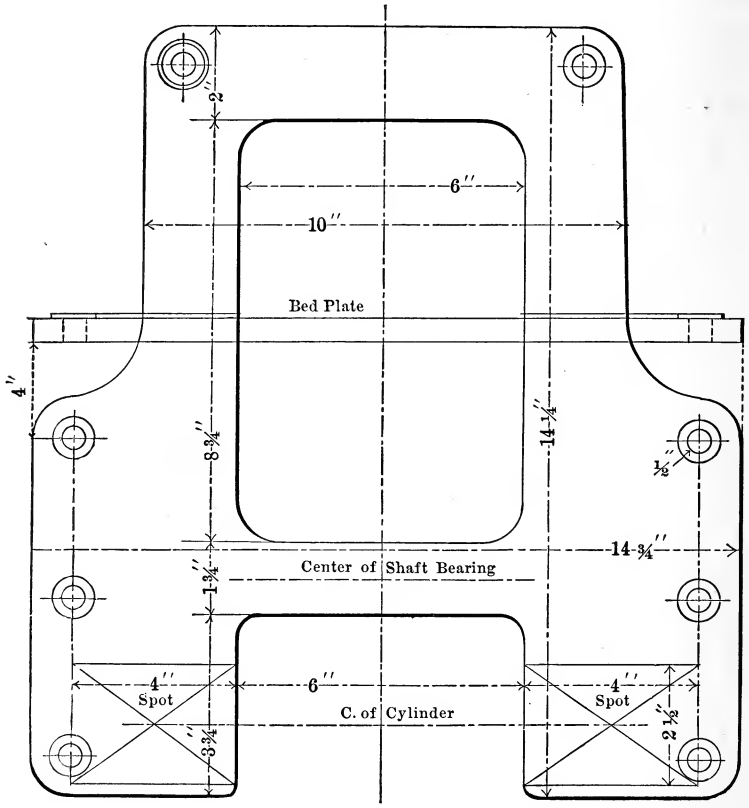
driven in tightly. This pin must be turned to fit, or it will work out when running.

Now suppose that all the parts are finished and ready to put together. The first thing to be done is to set the cross-head between the guides in the centre of them, measure top and bottom, and screw the frame up solidly on it with a couple of clamps, one on each side, being careful not to spring the frame, and being sure to screw up fairly on both sides. Observe also that the top and bottom of both frames bear fairly, as shown on a straight edge held across them and that they are square sidewise with the cross-head. It might be thought that the cross-head would prevent any distortion of surfaces by reason of its long bearings and its width; but this is not the case, and every operation must be verified before proceeding to the next one.

CHAPTER VIII.

HAVING the frame square and true in its place, set the cylinder in its place, with the bottom head on, and put in the piston and rod. See if the rod enters the cross-head fairly, and screws down in it easily without any bind or twist. Then examine the position of the cylinder with regard to the brackets and their bearing upon the head of the frame. A very slight coating of red paint on the under side of the brackets should be used, and the cylinder moved, or twisted a little sidewise, when the actual bearings will be shown. These last must be iron and iron, each part setting squarely on the other; if this is not done when the bolts are put in and screwed up there will be great distortion of the parts, and the cylinder will be thrown out of line with the guides. The noiseless action of the engine depends upon the accuracy with which the work is done. No liners, pieces of tin or brass, must be put in between the brackets and frame; all must be in actual contact. It is now in order to set the cylinder and frame on the bed-plate where it belongs, the holes having been previously drilled in the lugs on the bottom for the bolts. The frame must be carefully centred with a centre-line, drawn on the bed-plate

where the centre of the shaft comes, so that the crank will revolve equally, and the crank-shaft and pillow-block set in place to square by, or from.



BED PLATE, 3″ × 4″.

When this is done, take a sharp scriber and mark through the holes in the lugs onto the bed-plate to locate the holes. This must be very carefully

done indeed, and is a job for an expert mechanic, for there is no alteration possible after the holes are drilled. They must be reamed for turned bolts and no oblong, filed-out-on-one-side holes will answer. Unless the workman is absolutely certain of his ability to do this work properly, he should take the job to a shop where there are good workmen, and then watch the good workmen.

This holds good with the holes for the pillow-block also, every detail must be square and true with every other detail; when it is so the builder can turn his back on the engine at work and not know that there is one in the vicinity. The holes in the brackets on the cylinder must have been drilled prior to setting it in place; when it is finally adjusted, so that the cross-head works properly in the guides, put clamps on the brackets and frame so as to hold it firmly; then try the cross-head again to see if the cylinder has been shifted during the operation, then drill the frame through the holes in the bracket; and when the bolts are put in everything will be solid iron and iron, and the engine will be in line all over.

There are difficulties connected with drilling these holes just named in a lathe; on account of the size and shape of the parts they cannot be brought to the drill readily; where this is the case the job must be taken to a machine-shop where there is an upright drill-press.

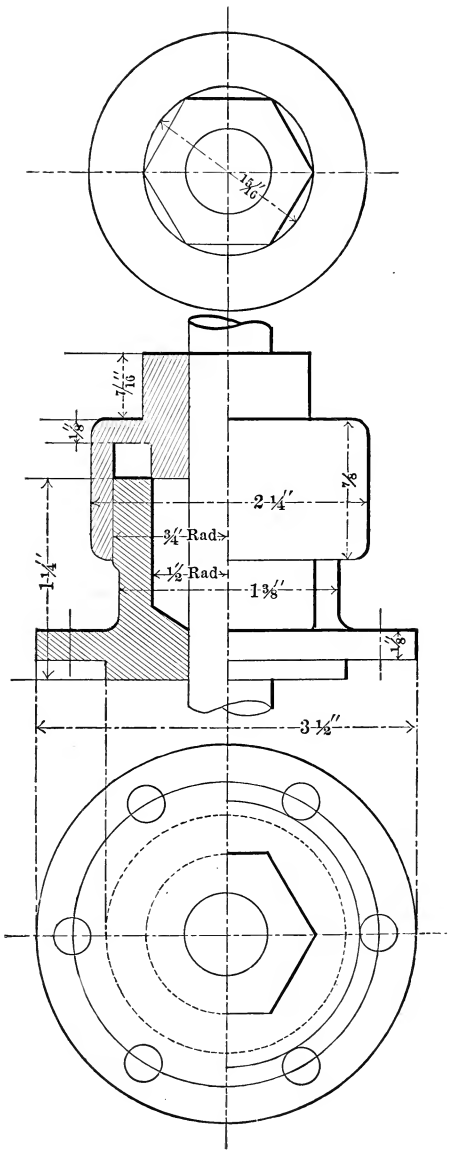
CHAPTER IX.

THIS engine, if constructed according to the drawings furnished (not mere designs, but working drawings from which an engine has been made), will deliver 5-horse-power easily at 800 revolutions per minute with 150 pounds steam-pressure; even more than that, but this is a fair average. Such an engine will drive a 25-foot boat by 5 feet beam, or width, 8 miles an hour, carrying 20 persons, or it will drive a small machine shop with several lathes, drills, and other tools in it.

If it is not desired to build so large an engine, the amateur can exactly halve the proportions all through and make a very neat model. This would give a cylinder 1½ inches diameter by 2 inches stroke; and the link motion can be omitted, using instead of it a single eccentric, with no reverse motion, directly connected to the valve-stem.

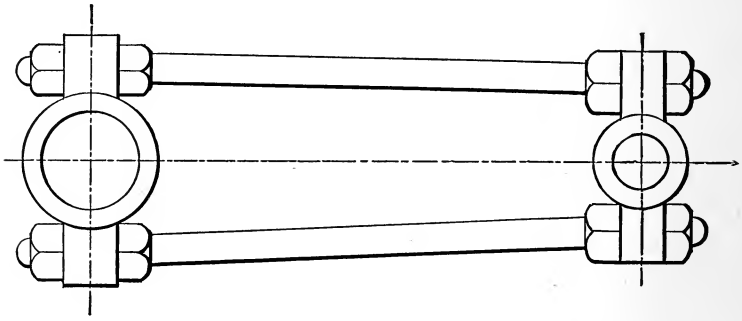
If a horizontal engine is preferred, a design for the cylinder of it, 1½ inches by 3 inches is given (page 58); the other proportions used in the vertical engine will also answer for this engine. Changing the position of the cylinder makes no difference in the sizes.

No bolts need be made for these engines unless


7/16"
7/16"
1/8"
2 1/4"
7/8
3/4" Rad
1/2" Rad
1 1/4"
1 3/8"
1/8"
3 1/2"

they are under $\frac{1}{8}$ of an inch, for machine screws are so universally used that they can be had of all sizes in any tool store; the same is true of nuts. Bicycle parts, or nuts at all events, can be had nickel-plated, if needed, down to $\frac{1}{4}$ of an inch in size.

The crank-pin connection shown in the details of the 3-inch cylinder is so made from the fact that the rotative speed is high, and it is necessary to avoid all parts that are liable to get loose, but another form of connection which admits of greater



adjustment is here shown which requires careful attention to make it properly. It is commonly used upon large vessels. For those who cannot get forgings made a connecting-rod made in part of steel, or iron rods, is given.

Referring to small parts suppose it is necessary to have a check-valve for a small boiler, the water-passage being not larger than $\frac{1}{8}$ of an inch. Then get a brass rod $\frac{1}{2}$ inch in diameter and $\frac{3}{4}$ long, and put it in the chuck. Drill a $\frac{5}{16}$ hole in it $\frac{3}{8}$ deep, then drill a $\frac{1}{8}$ hole through it. The

larger hole must be drilled first, for its bevel forms the valve-seat, and being held steadily makes the seat true and without chatters. Now take a small tool and enlarge the $\frac{5}{16}$ hole to $\frac{3}{8}$ just around the seat where the valve comes. This leaves a chamber inside, and the thread for the cap or pipe-connection to the valve-chamber is to be cut on this with a chaser. In the end of the cap which is screwed into the valve-chamber a hole $\frac{1}{8}$th in diameter is to be drilled for the end of the valve spindle as a guide, and the valve is made from a brass rod, in an obvious way, ground to its seat. Cocks are made in the same way from brass rod large enough for the job, or from small castings. Small pipes of any thickness metal can be had from pencil-case makers who draw tubing of $\frac{1}{32}$ bore if needed. These are silver soldered, and tight against ordinary pressures. They cost very little.

It must be borne in mind that simply turning or boring objects or details to size does not imply that they fit each other, for in most cases they do not. Fitting means that the several details are in absolute contact over their whole surfaces; a very different matter from merely filling holes without shaking. It is not so easy to fit a round pin to a round hole when they are of small diameter, either by turning or filing, and the only quick and sure way is to grind the parts together. To do this well requires experience and patience; it is not a job that can be forced or driven but must go

naturally along through regular stages. The holes are, we will say, ¼ inch in diameter; now having drilled them closely to the size, take a reamer and ream them out, which will make them cylindrical at least. Then turn the pins full to the size, so they will push in tightly, and then apply oil and floated crocus to the surface, rotating the work and drawing the pin in and out during the operation. This is very soon done, and the time taken is well expended if a fine job is required; but the work must be thoroughly washed when completed, so that none of the grinding material remains on it.

Another method of fitting is to scrape the surfaces so that they are in contact, and for an amateur this is far easier than it is to file them. Scrapers are of two forms practically, a flat nose and a triangular point, made by grinding a saw-file slightly convex on the point; also a diamond-point hand-tool can be used to good advantage. The main brasses of the engine, shown in previous chapters, are bored to size but they must be fitted to the shaft bearing carefully, so that they will not heat or pound at high speeds. They are bored together in the pillow-block they go in, and each half must then be taken out and tried on the shaft with a very slight coating of red-lead on the journal; by rubbing the brass on this it will be seen that they are very far from fitting, even though the bore is apparently smooth and true. All the inaccuracies must be taken out by scrap-

ing. The same course must be followed with the valve and seat.

Amateurs may use a return-crank motion to drive the slide-valve instead of an eccentric, for in some places it is very convenient. A return-crank is shown in Fig. 6, and is very simple to make; but it must be used with a valve without lap, as it can only have a very small lead or opening, as will be seen from its construction and principle. The stroke of the valve can be materially changed by moving the shaft end of the return-crank to or from the centre of it, but the lead remains practically the same. For a small horizontal engine the return-crank is very satisfactory.

The design herewith is similar to that of the Corliss engine with the exception of the valve, which is a slide. The cylinder bolts directly onto the end of the frame; and the pillow-block and guides are bolted to the bed-plate by screws, as shown. The guide is a tubular casting, bored and reamed true in the lathe, and faced and turned true on one end before removing it from the chuck. This end fits the cylinder and forms the front head, so that when the parts are put together there is no lining up to be done, and the cylinder is absolutely in line with the guides. After the guides are bored they are cut open by drilling along the central line, and on the edges of the cut a brass rod slotted or sawed for its whole length is fitted. This hides the raw edge and makes a neat finish; or an iron rod can be used if preferred.

CHAPTER X.

ONE–HORSE POWER HORIZONTAL ENGINE.

In this example of a horizontal engine all the work can be done on a lathe, which is a matter of some importance to an amateur without facilities for planing; filing true surfaces of any extent is also a tedious and sometimes an unsatisfactory job; in this engine the cylinder, valve-face, steam-chest, and guides are all completed in the lathe, and the guides are accurately centred in place, so that there is no lining up to be done to make them come exactly true. The cross-head is also turned in the lathe and, in a few words, the fitting and vice work is reduced to a very small quantity. Any amateur who is a fair lathe-hand can make a nice piece of work out of this design.

It is proper to make a few remarks here about the power of these small engines. As generally made they are mere toys, of no value except to look at a few times and are then thrown aside; but this is not the case with the example shown. The reason for the inutility of small engines is that they are not designed to do any work, but are hastily thrown together, with inadequate bearings and wearing surfaces; they speedily work

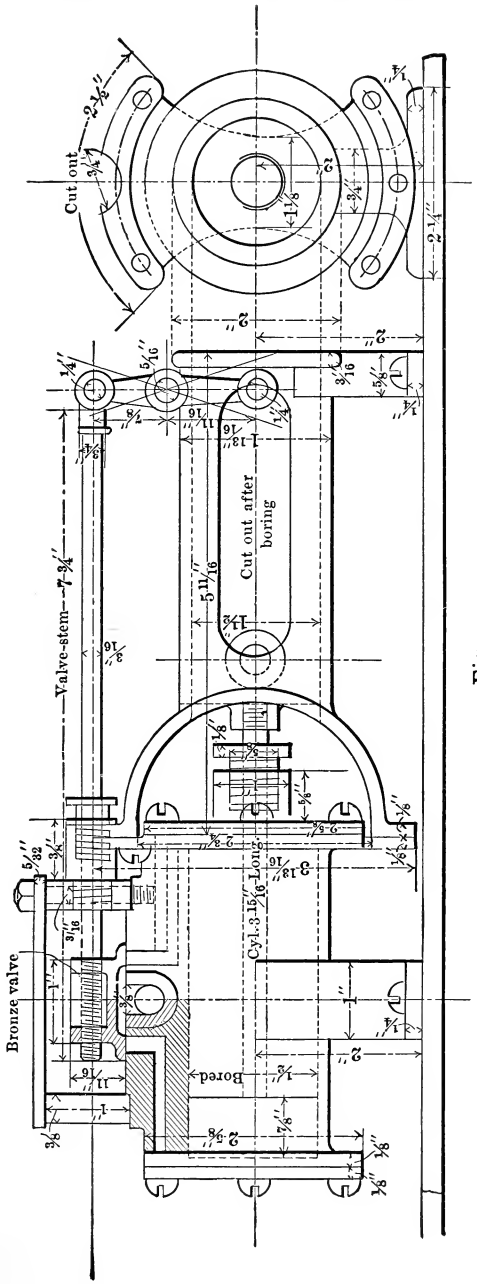

Cut out
Cut out after boring
Valve-stem
Bronze valve
Cyl. 3 15/16" Long
Bored

Fig. 13.

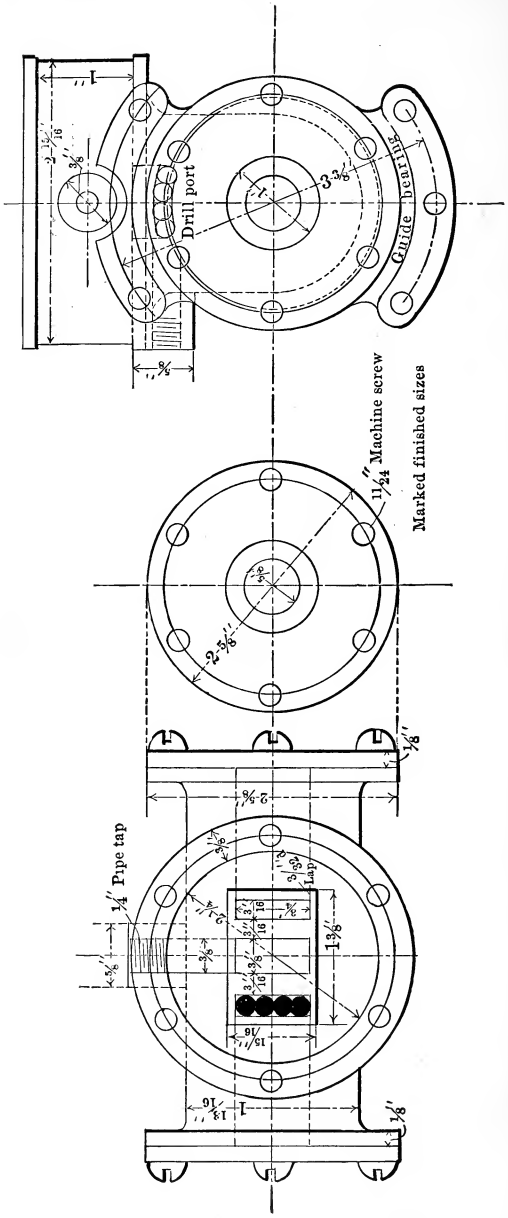

Drill port
Guide bearing
Machine screw
Marked finished sizes
Pipe tap
Lap

Fig. 14.

loose all over and are mere rattle-traps and eye-sores to mechanics. The boilers used with them are of no value either, and are incapable of generating steam enough at high pressures to do any work. With the boiler shown (of the vertical type) this horizontal engine will easily deliver 1½-horse power at 600 revolutions per minute and 100 pounds steam pressure; and it will do good service for years if properly managed, notwithstanding that the piston is only 1½ inches in diameter. A small piston running at high speed with reasonable pressure (not under 75 or 100 pounds) will do a good deal of work; the author has in mind one of 2½ inch cylinder by 6-inch stroke which, with only 40 pounds steam pressure, runs a small wagon-maker's shop, having lathe, drill press, and bolt-cutting machines. The cost for fuel is nothing, while the advantage of having power at hand enables men with small shops to earn a good deal more than they could with hand labor alone.

In this horizontal engine all the bearings are larger than strict proportions require, but that is an error on the right side, and, while it is not contended that this engine is fitted to drive a small shop, unless it be for amateur work, it has the ability to do so on occasion if required. It will readily drive a 16-inch engine lathe, or a bolt-cutting machine up to 1-inch diameter of bolt.

Referring to the engine itself patterns will have to be made for all the cast-metal details;

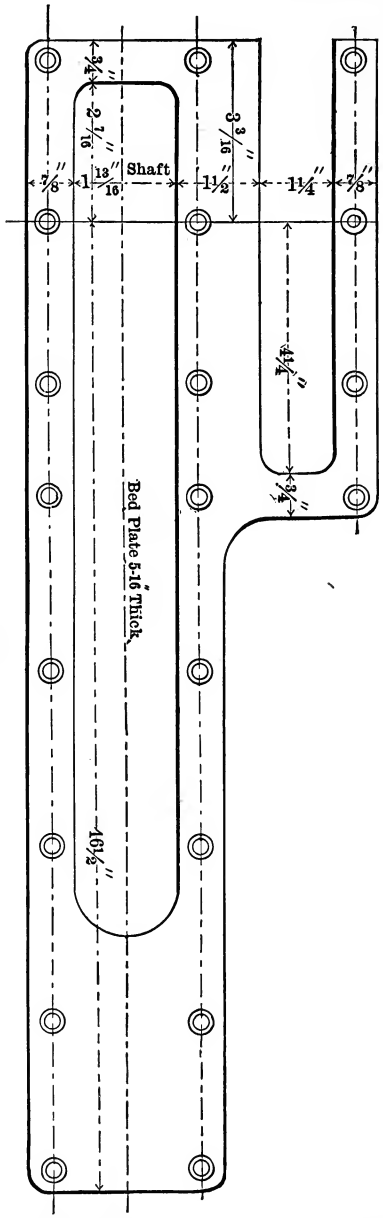


Fig. 15. BED-PLATE OF HORIZONTAL ENGINE.

having these the execution of the work can proceed rapidly. In all jobs of this character the object sought is to do as little useless work, or re-handling as possible. All the lathe-work on the cylinder should be done in sequence, as far as it can be; not a part at one time and another subsequently. The cylinder, in this case, has no ports cast in it, they being too small for handling for the average moulder; they must, therefore, be drilled in, as shown in the drawings.

To do this put the cylinder in the vice and roughly dress off the valve-face so that lines will show on it. Get a piece of blue-stone, so called, wet it and rub it over the valve-face; this, when dry, leaves a deposit of copper on the face of the work so that lines will show clearly on it; then lay off the ports as per drawing. Having done this get a drill $\frac{1}{32}$ smaller than the finished width of the part and drill down to the depth shown on the drawing, leaving but little metal between the holes as shown. Then, having previously laid off the ports on the ends of the cylinder, drill through to meet the holes in the valve-face; when all the holes are drilled, make a drift, or square-ended chisel, and drive out the metal between the holes. This operation requires care to make it successful and there should be several drifts, each a little wider than the rest, so that no great amount of metal is removed at one cut. The end of the port where it comes against the cylinder-head is to be cut down to the bore, thus establish-

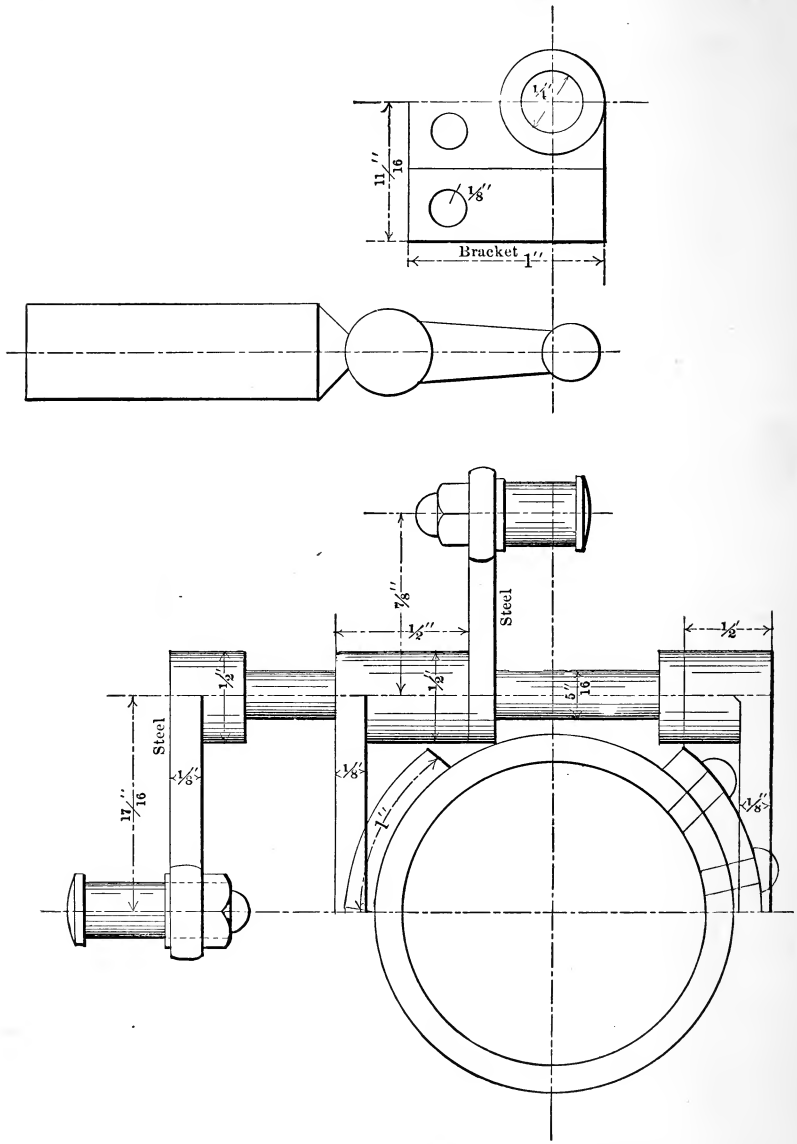


Fig. 16. Valve Gear of Horizontal Engine.

ing connection to the piston. There is ample metal left in the bore to do this work, but amateurs must be careful not to drill too far, or so

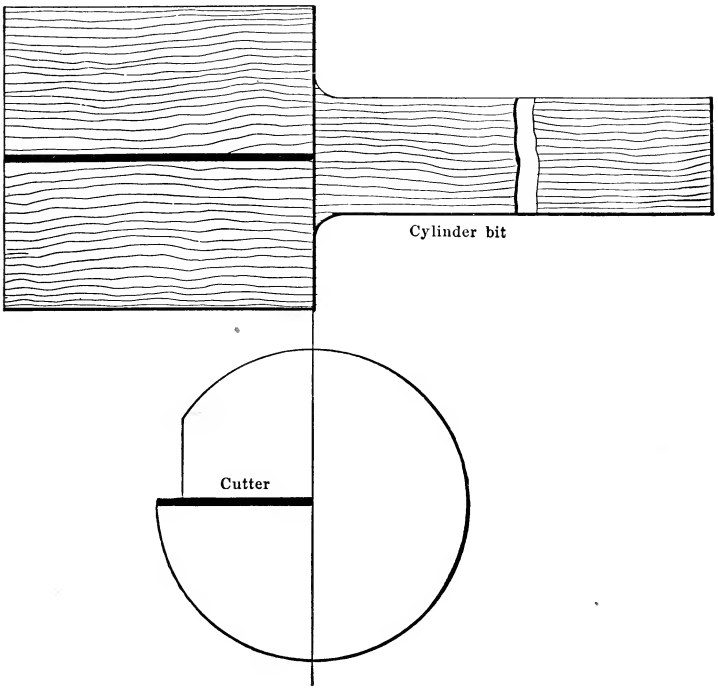


Fig. 17.

that the point of the drill would penetrate the bore when it is completed. Cutting the ports must be done first, so that subsequent operations will not injure the faces.

If this job is got through with properly, chuck the cylinder and face off the back end of it; then turn it end for end, and face the other end, and square the flanges where the guides come. This should not be done to dimension at first, but merely to get the heaviest part of the stock off. Then run a cut through the cylinder and bore it within $\frac{1}{32}$ of the size. Very few amateur lathes will bore a true, parallel hole of any length, so it will be necessary to make a bit to do this properly. This bit is merely a reamer, and it leaves the bore absolutely true and parallel. The engraving shows the bit. It is merely — in its simplest form — a wooden stock with a steel cutter inserted in it, and as amateurs have little use for special tools, it is made as shown to meet their needs. Take a piece of any close-grained wood, maple or beech, about 6 or 8 inches long, and turn it as shown; make a saw-cut the whole length of the boss, down to the centre, and insert a piece of sheet-steel $\frac{1}{16}$ of an inch thick. This must be filed off to the surface of the wood, and backed off so that it will form a cutter; harden the steel to a violet-blue and, having started a cut in the bore of the right size for $\frac{1}{4}$ of an inch, put in the reamer or bit and feed up on the tail-stock screw. This will make a true bore as smooth as a looking-glass; there is no occasion to counter-bore this small cylinder, the heads fit right to the bore. The flange and guide-seat are now to be squared as the last thing, just scraped, so as to bring them true with the bore, and the outside of

the flange turned. It is well to be very careful on this operation, for if the tool catches in running it in or out, or in setting it, and the cylinder is shifted, trouble will ensue; it can never be set exactly true again, the only resource is to put the cylinder on an arbor, or mandrel, and square it in that way.

We have now to deal with the valve-seat and steam-chest flanges, and to do this the cylinder must be chucked so as to bring the valve-face in the right position; or the valve-face can be trued by putting a piece of iron in the exhaust-port for a centre, and another centre in the foot, or leg, on the cylinder, to sustain it; this is much the easiest way for an amateur and the quickest also; but in truing the bottom of the cylinder bearing, or foot, care should be taken that the bore is exactly at right angles with it. To attain this put a piece of wood across the bore and mark the exact centre of the cylinder on it; then swing the cylinder against a fine-pointed tool in the tool-post and centre it exactly; be very careful in maintaining the centres exactly while turning the flanges on the valve-chest and the foot, for if the latter is not square with the bore the cylinder will cock up in front, or at the back, and the bearing on the end of the guide where it is fastened to the bed-plate will be a good deal out of the way; the thickness of a piece of thin paper, even, on the cylinder-foot, will throw the guide-foot off over $\frac{1}{16}$ of an inch.

In squaring the flanges for the steam-chest seat

and the valve-face it will be noticed that the latter is $\frac{1}{16}$ of an inch higher than the former; the ports must be stopped with wood so that the tool will not dodge into them and mar the edges.

Having the cylinder all dressed up in good shape the steam-chest is to be taken in hand and faced up. This can be done easily and quickly in the chuck, and the whole work done without removing it. Catch the chest by the outside of the chuck-jaws in the bore of the chest (there is no need to bore the chest inside) and turn it all over outside and square the faces; before removing it from the chuck put a little fine emery on the face and hold the cylinder up to it on a fast speed; this will grind both faces steam tight so that it will not require a joint.

Mark this face and the cylinder-flange with a small centre-punch so that it can be put on its own face when assembling. Now take the steam-chest cover and finish it up all over and grind it to the steam-chest also; while it is in the chuck scribe a fine line on the face where the bolt holes are to come, so that they will all be central. Do not drill any hole in the chest-cover for an oil-cup, none is needed. It will be seen that the valve-stem stuffing-box screws into the chest, so that the latter can be turned all over.

Now take the guide in hand and bore it out with the same bit that was used on the cylinder, for both are of the same size; then put it on an arbor (a wooden one will answer if it has metal

centres), and square up the flanges where they go on the cylinder, and also the front end of the guide; it will serve to show whether the whole sets square on the bed-plate by using a try square on the bed-plate in assembling.

It will be observed that the guide-flanges are checked on the cylinder-flange, but the engraving is so small that it doesn't show very plainly. This is done to centre the guide with the bore, so that when set on its seat, there will be no adjustment required of any kind. The foot, or leg, on the front end of the guide will have to be dressed square in the vise, as it cannot be got at in the lathe. Set up all the parts together, cylinder and guide, and then put it on the bed-plate before taking anything off of it, and do not drill the holes in the cylinder-flange of the guide-bearing; the guide-flanges should be drilled. When it is found that both the feet are square on the bed-plate, then the holes in the cylinder-flange can be marked off carefully and drilled; without this precaution the cylinder and guide-flanges might be set on a cock-bill.

Now let us take the crank-disk in hand; this, also, will require careful work. Turn the face outside and on the edge, all over, then put the face side next the face-plate, and bore the shaft-hole, and face the hub at the same time. Then lay off the crank-pin hole by scribing the centre of it with a sharp-pointed tool exactly 1½ inches from the centre of the shaft. Remove the disk

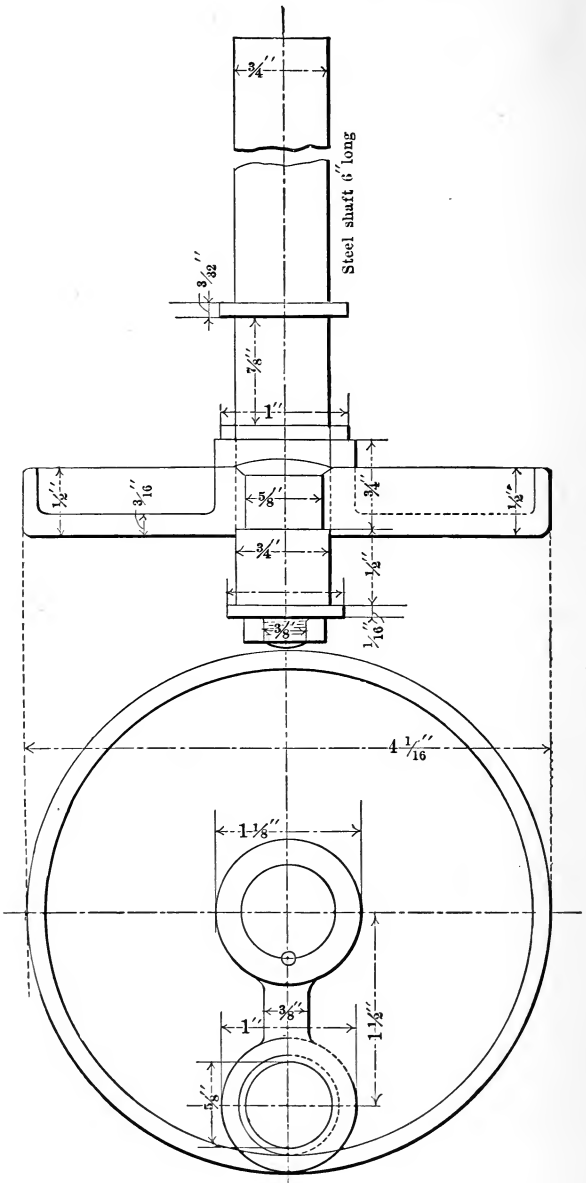

3/4"
Steel shaft 6" long
3/32"
7/8"
1"
1/2"
3/16"
5/8"
3/4"
1/2"
3/4"
1/2"
1/16"
3/8"
4 1/16"
1 1/8"
3/8"
1"
1 1/2"
5/8"

Fig. 18.

and lay out a ¾ hole on this centre, and centre it on the face-plate so that it is ready for boring.

Much depends on the integrity of this job; for if the crank-pin is not absolutely square with the shaft, the engine will never work silently. The crank-pin being out of square throws the connecting-rod twice the amount of the untruth in a revolution, and that, in turn, lifts or twists the cross-head in the guides, a result that can never be remedied in any way except by making a new crank. In fitting the shaft to the hub leave it a trifle larger than the hub, the merest shade that can be felt, or so it will barely enter the hub, then heat the latter enough to expand it, and put the shaft in and let it cool; the shrinkage will hold it securely, but there is a steel pin driven in, as shown, to make sure. After the crank is shrunk on in place, turn all the bearings and finish the shaft to size, but do not turn it end for end in the centres; if these last run out a little bit, the bearings will be out of truth with each other, the axes will not coincide; the crank-face and rim should also be turned up and polished at the same time. The crank-pin should be a driving fit and riveted over on the crank-hub; turn that end of the pin slightly hollow so as to leave a raised rim all round it; by flattening this down on the crank, very little hammering will be needed to make the pin tight.

The pillow-block brasses are to be fitted in and then bored to size, after which they are to be

squared on a mandrel while in the block. Here is where an angle-plate comes in very aptly on a lathe, for by squaring the base of the pillow-block

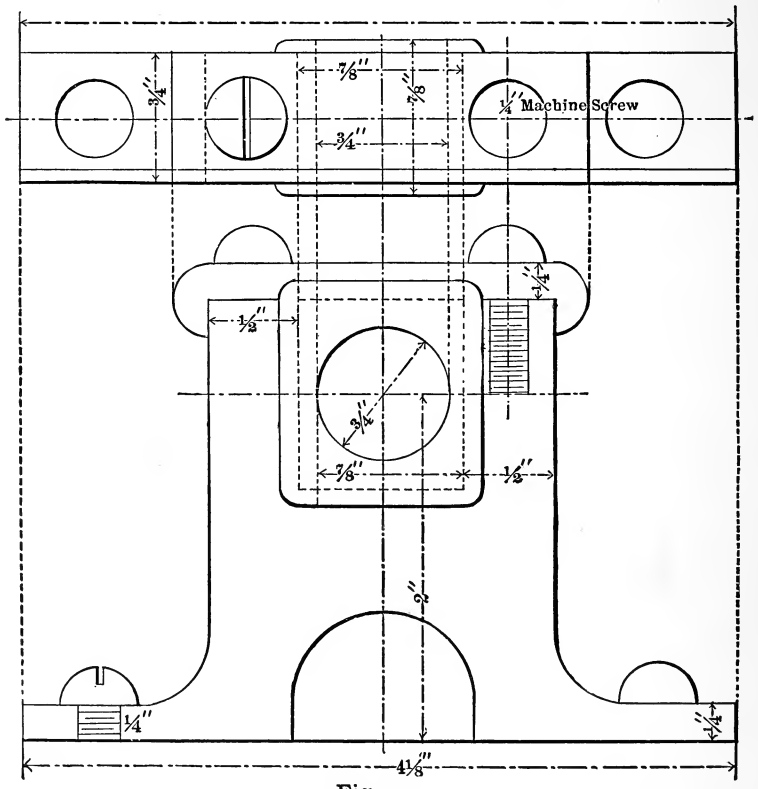


Fig. 19.

in the vise, or between the centres (which is the better way), the brass can be set on the angle-plate and the brasses bored exactly to the distance marked without using a mandrel.

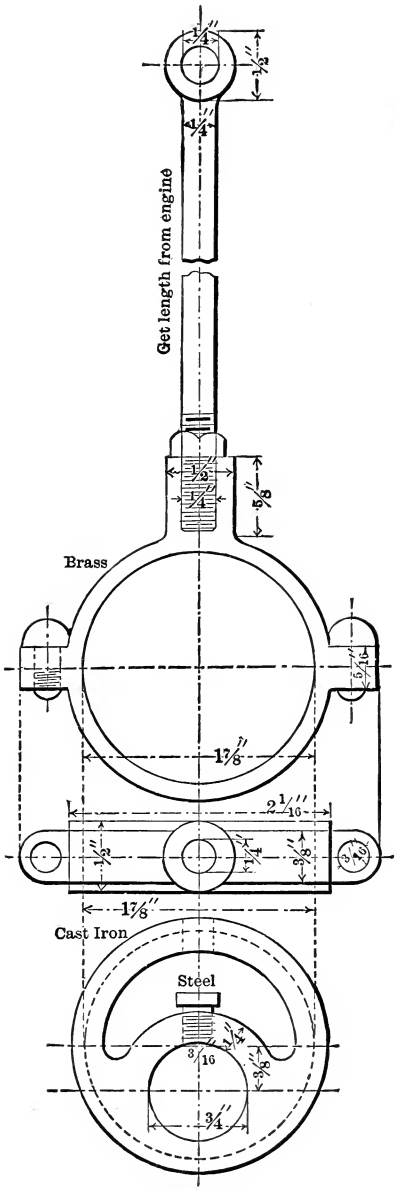


Fig. 20.

The eccentric can be faced on both sides, turned on its diameter for the straps, and afterward shifted on one side $\frac{3}{8}$ of an inch to bore the shaft-hole. The straps should be cast in two parts, faced on the lugs, then soldered together, and the bolt-holes drilled the size of the tap-hole, enlarging the other strap-hole subsequently; the straps are to be bored when soldered, and afterward melted apart. The hole for the eccentric-rod can be drilled and tapped better when the straps are asunder.

The valve can be faced in the chuck, although it is so small that it is just as easy to dress it in the vise; it should not be ground to the valve-face, but scraped to a true bearing. The valve gearing, rocker-arms, etc., require no explanation; they are all of steel, and the arms are made as shown in the diagram on page 75; take a piece of round machinery steel large enough for the job and turn it up, as shown, to the outer dimensions of the arm. Then file it off — while still in the chuck — on opposite sides for the hubs. Do not cut it off of the piece, but take it out of the chuck, and drill the holes for the shafts through the hub and for the pin; having done this and found out that the holes are parallel with each other (by putting tight-fitting rods through them and squinting across them), cut the arm off the piece, put it on a small mandrel and square the hubs true; the body of the arm can also be turned flat for a short distance as a guide to filing

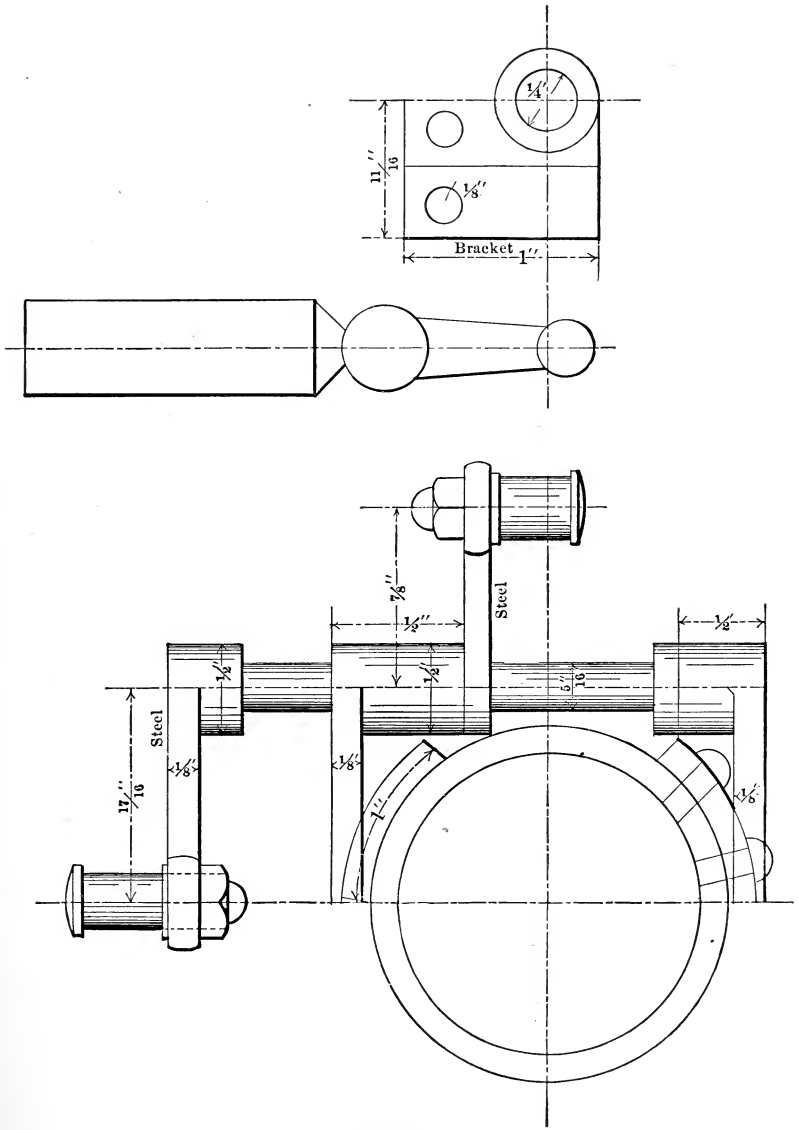

1/4"
11/16"
1/8"
Bracket 1"
7/8"
1/2"
Steel
1/2"
1/2"
5/16"
1/2"
Steel
1/8"
1/8"
17/16"
1"
1/8"

Fig. 21.

it later. Very small details can be made in this way accurately which could not be readily handled in any other way, neither caught in a vice or held so as to shape them.

Now in drilling the holes for the steam-chest and cylinder covers a word of caution will not be amiss. Nothing causes more annoyance when assembling than holes that do not come fair, and tapped holes that will not admit the bolts because they do not coincide. It is easy to avoid this trouble by following this plan: select the drill to be used for the taps and drill the holes with that first, clear through as far as it is to go, then enlarge the holes the bolt is to pass through afterward; by doing this the bolts will enter fair every time, and the bodies will be a snug fit to the holes. Lay the holes off in the steam-chest cover and the cylinder covers of this engine accurately and mark the centres; then drill two holes on opposite sides and tap them for the bolts. Put the parts together and screw them up tight; then drill all the other holes clear through, as they are to be when complete.

In turning the piston see that it is a snug fit to the cylinder; there is no packing in it, for none is needed; but the piston must fit closely and yet run free. The centres in the piston-rod must be left in, and also in every piece that is turned, and they must, in all cases, be drilled. No centre-punch centres should ever be used for anything.

It is proper to here call the amateur's attention to a method of finishing small cylindrical castings where a scroll chuck is not available. In this case a wooden chuck is made and bolted on the face-

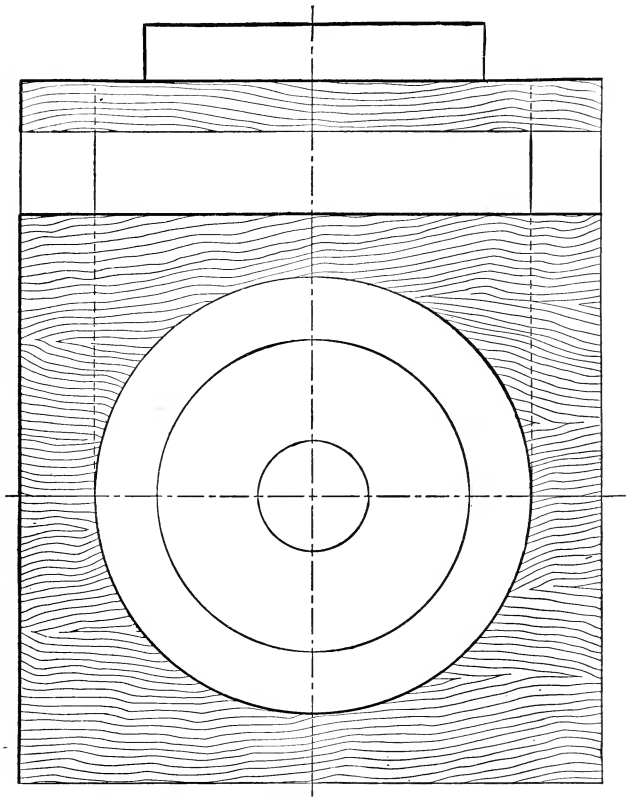


Fig. 21.

plate; it is then turned out so that the casting will drive in tightly, the edges of the casting, or flanges, being turned when on the cylinder.

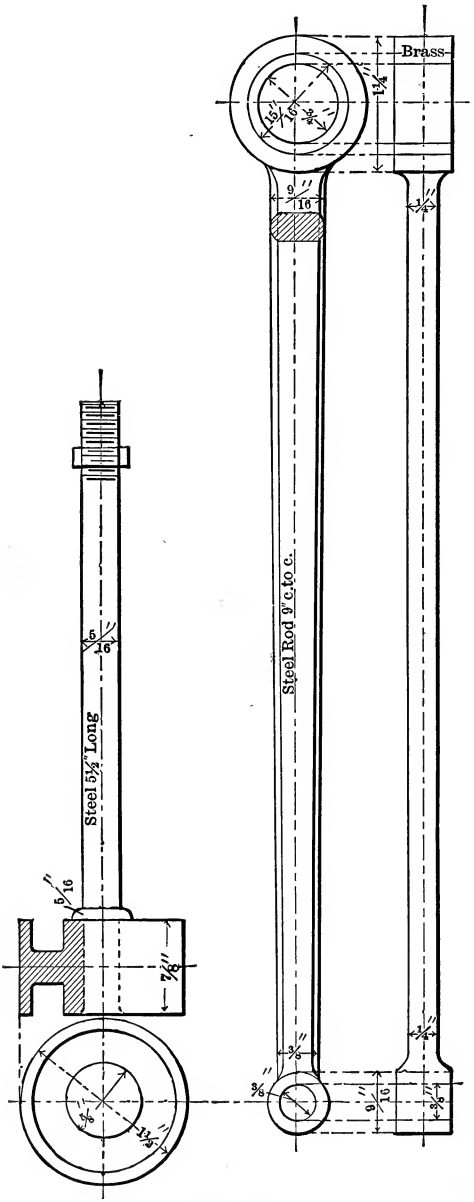


Fig. 22.

The connecting-rod is a simple job, but the pin-holes will have to be bored on a lathe which will swing the rod. This rod is made with solid ends, for the reason that the engine runs very fast, and small details will work loose in spite of good workmanship. The crank end is bushed and will run a long time without wear if the pin is a good job when first made; when it gets too slack, it is a very simple task to put in another bush.

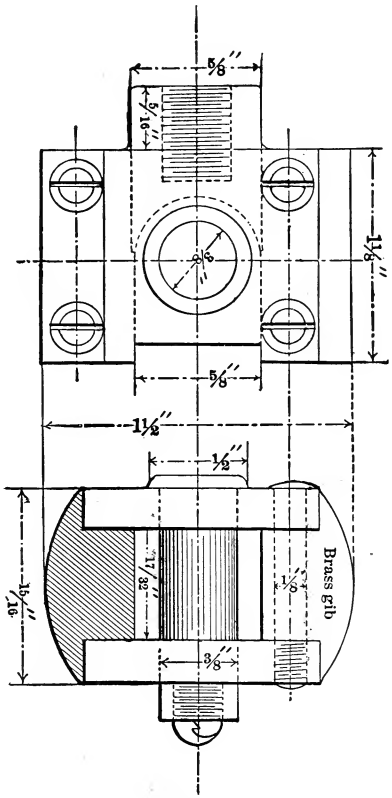


Fig. 23.

The cross-head is of cast-iron with hard brass gibs let into the jaws, which are held by two bolts in each jaw. The cross-head can be all squared and trued up in the lathe, and it should be finally turned on its guide faces when on the piston-rod. This may not be possible on some amateur lathes, as it needs a steady rest; lacking this the cross-head can be screwed into a short mandrel held in the chuck.

The fly-wheel may seem small to some, but its circumferential velocity is high, over 1,200 feet

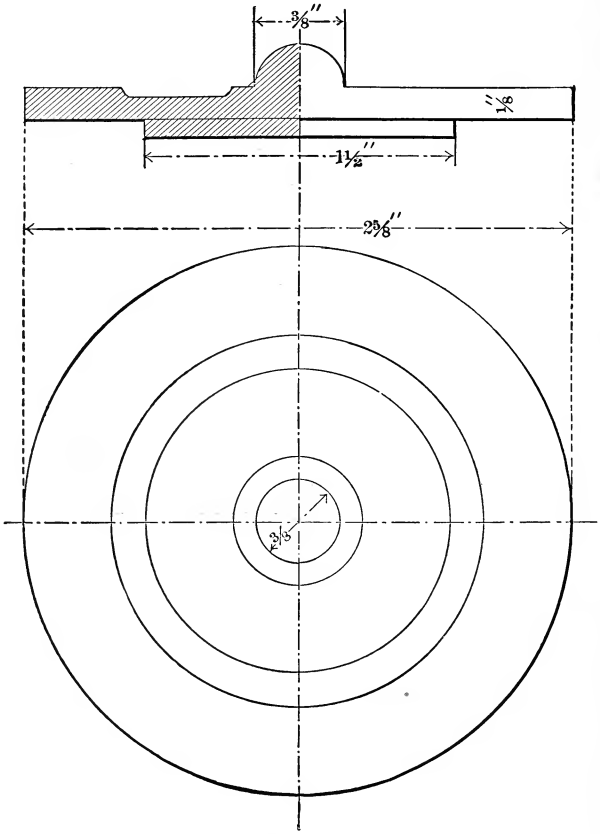


Fig. 24.

per minute at 600 revolutions per minute, but it is amply strong to do its work. It is very necessary that it should be absolutely true at this

speed, and it should be secured by a key sunk in the shaft; this key way must be cut before the shaft is finally turned, or the cutting of it will make the shaft run untrue.

This covers all the details of the horizontal engine and, as stated in previous lines, it will be

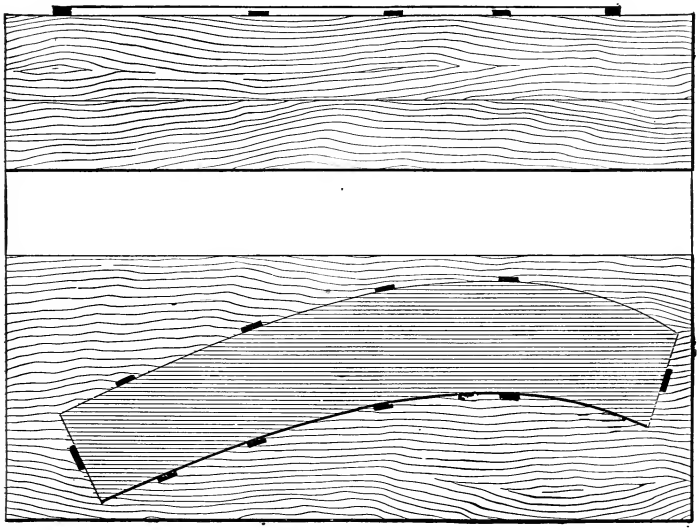


Fig. 25.

found wholly satisfactory in action. The method of setting the valve is the same as that shown for the vertical engine.

Now let us consider a few points in regard to finishing details which sometimes puzzle amateurs. There are parts sometimes which are very thin

and have irregular outlines also; these cannot be caught in a vise, but must be treated as shown

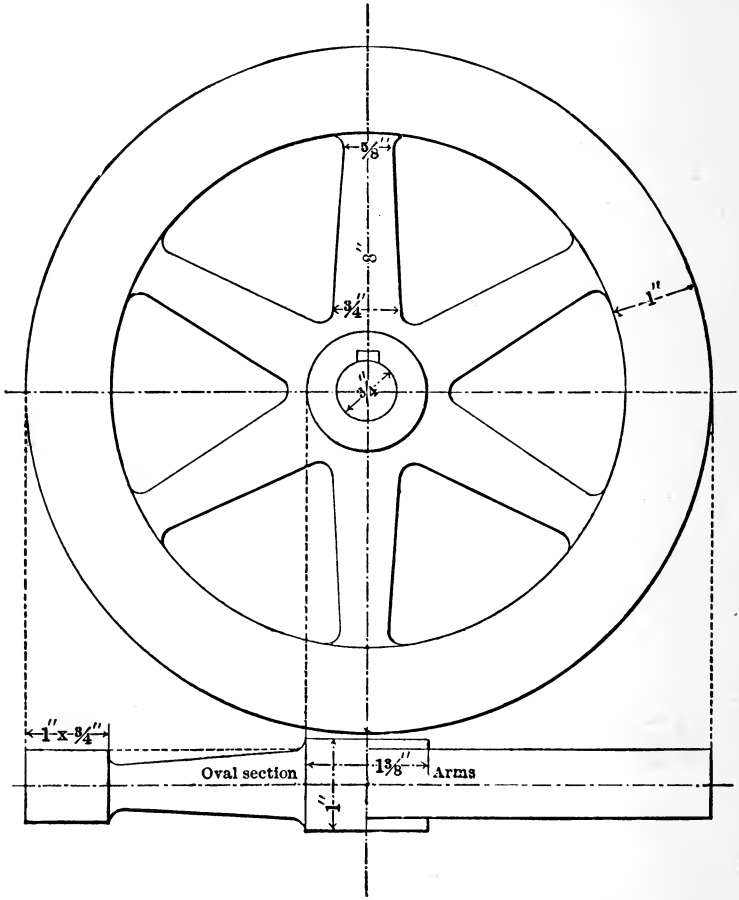


Fig. 26. Fly-Wheel of Horizontal Engine.

in the engraving. Get a piece of hard wood, preferably of the right size, and plane it true on

one face; then nail a strip on the back about an inch square to catch it in the vise. Take the piece to be draw-filed and, laying it on the block, drive brads in all around the edge, so as to have a wedging or clamping action when driving; sink the heads below the work and there is then a flush surface on the work which permits anything to be done on it.

It sometimes happens that an engine will not run when steam is turned on, and this has puzzled a good many mechanics at times. The cause in every case is that the slide-valve is off its seat, or cocked in some way by the valve-stem nut binding it so that it will not seat square. Sometimes it is caused by the gland in the stuffing-box being untrue; whatever the cause it must be removed or cured before the engine will work properly, and this caution is given to enable those who may have any trouble to find and remove it.

CHAPTER XI.

SETTING THE ECCENTRICS.

SOMETIMES persons are puzzled in setting the eccentrics of engines, and do not get them in the right place on the shaft without a great deal of labor; not even then sometimes; but the matter is a very simple one, and easily understood. It does not take so long to do the work as to tell how it should be done.

An eccentric is merely a disk with its bore on one side of its mathematical centre, and has, from this fact, an eccentric, or irregular motion; but it has no other peculiarity, or special fitness, for opening and closing steam-valves. It is no more or less than a continuous or circular crank, where crank and pin are combined in one body. It is supposed to have, by some, an irregular velocity, but this is not correct, for any given point in its body moves at a regular speed around the shaft, the same as a crank-pin does.

There is a long side and a short side to an eccentric, so to speak, and the side nearest the shaft does move more slowly than the long or opposite side, but the velocity of the wheel itself is regular around the shaft as before stated; the

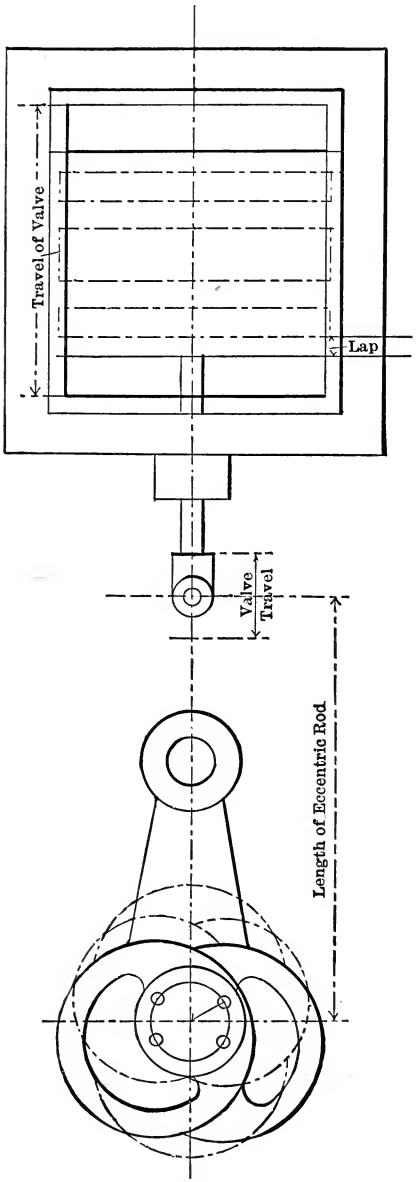


Fig. 27.

only variation being as it approaches the centre or points of no travel, when changing from one direction of motion to the other. The idea of an irregular motion was doubtless obtained from looking at the long side and at the short side alternately. The throw of an eccentric is the distance from the centre of the wheel to the centre of the shaft that it is on; the stroke of the eccentric is twice the above distance. These terms are not the same, and should not be used as if they were. The stroke of the eccentric has no effect upon the times of the valve action. The *travel* of the valve operated by any given eccentric can never be changed after it is once constructed; that is, fixed by the difference or distance of the shaft centre from the centre of the eccentric itself; it is only the times of the travel that can be altered by rotating the eccentric around the shaft.

Let us take an imaginary valve and eccentric to explain this more fully. The width of the steam-ports is 1 inch, and the lap is half an inch; the lap added to the width of the port gives the throw of the eccentric or its travel in one direction to open one port fully; manifestly, this is the throw (distance of the centre of the shaft hole from the centre of the eccentric), because in a complete revolution the valve travels the same distance in the other direction; it is then said to have 3 inches valve travel.

Having settled these minor points, let us con-

sider the actual process of setting any given valve, slide, piston, poppet, or any other.

The same processes apply to all, modified only by the valve gear; of this last there are endless types, and only those in common use all over are alluded to.

The engine being connected in all parts, it is required to know where the eccentric should be set to open and close the ports properly. If the eccentric-rod is attached directly to the valve-stem, the position of the eccentric can be fixed at a glance by an engineer of experience; but first he finds out whether the valve runs square as it is called, before he attempts to set the eccentric itself. If the engine is a small affair the whole of the details can be connected together, and the shaft revolved; if the engine is large this last cannot be done without much labor and an expenditure of time which is quite unnecessary. For instance: to find the correct length of the eccentric-rod.

Place the valve at mid-stroke, lap equal at both ends, and turn the eccentric, not the shaft, up so that its longest part is toward the steam-chest, whether vertical or horizontal. Now take the eccentric-rod and strap attached, and put the strap where it belongs, noting the position of the connection to the valve-stem and that on the eccentric-rod; mark the difference, and then turn the eccentric in the opposite direction and see where it comes on that side. If the eccentric-rod travels

equally on each side of the centre of the valve-stem connection the eccentric-rod is of the proper length; if it does not travel equally shorten the valve half of the difference only until it shows true. When the valve throws square set the eccentric (to make the matter simple), as in the diagram, and revolve the shaft only; there is no occasion to drag a heavy piston and connecting-rod, with their attendant friction, back and forth. If the valve has too much opening (lead) when the crank is at the end of the stroke, turn the eccentric-wheel on the shaft (do not change the valve-stem or eccentric-rod length) until the opening is equal on both ends. Then the valve is in its proper position to mechanically open and close the ports; but its real position for the best results must be ascertained by indicator diagrams. Of course the reader understands that the crank is on its dead centre in all of the above movements.

The Link Motion.

The operation just described applies to a common, straight connection, and it is modified to some extent by rocker arms and the details of the valve-gear; but the operation is practically the same in all cases, no matter what the details may be. Take the link motion used for reversing,—this also has been endowed with purely imaginary functions, the link itself being supposed to have some part in the operation of the valve when it is merely an adjunct to facilitate reversing direc-

tions of motion; the link, as its name implies, being merely a curved strap to hold two eccentric-rods at a given distance from each other, and admit of one or the other rod being thrown in or out of gear at will. Erratic motions and actions of the link are not caused (or cured either) by change of its form, for what is gained in one direction is lost in another; but erratic motions are caused by the length of the link itself, the length of the eccentric-rods, and the throw of the eccentric. This is only another form of saying that if the radius of the link, its point of suspension, the length of the rods, and the throw of the eccentrics are not properly designed in the first instance, there will be an erratic motion of the link at one or more points in its stroke. Take the radius of the link for example: This is conventionally the distance from the centre of valve-stem connection with valve at mid-stroke to the centre of the shaft; but sometimes if the connections are very short, indeed this gives a very awkward link, of short curve, — so that the link block binds or works hard; then the link is made of longer radius than the centre of the shaft, or of such proportions that the engine will reverse easily.

If the engine works at full stroke all the time this doesn't matter, for the valve can be made to work properly at full stroke, regardless of the link radius. If, however, it is intended to work expansively then difficulties arise at once if the link is of an improper radius, for the lead increases or

decreases alarmingly with any shift of the link if the rods are straight connected or "open," as it is called. If the rods are crossed then the lead decreases toward mid-gear.

It might be supposed that when the rods are of the proper length and the link is of the correct radius then there would be no motion of the valve with the link in mid-gear, but this is not the case, for it will be observed by the diagram that the centres of the eccentric wheels and the centre of the shaft are not coincident; so that in a complete revolution there is an eccentricity of motion equal to half the distance of the variation mentioned, so that there will always be a motion of the valve in mid-gear independent of the throw of the eccentrics themselves.

Now as to setting the eccentrics for the link-motion on a direct connection, the operation is the same as that for the single eccentric, — both eccentric-rods must be brought to the proper length to make the valve travel square before anything else is done; after that the eccentrics are fixed on the shaft midway between vertical lines and horizontal lines drawn on the shaft, that is to say, about quarter-stroke, and opposite to the crank-pin, as in the diagram. The shaft can then be turned once, a complete revolution, to verify the lead, and the job is done; the eccentric will only have to be moved a little, one way or the other, to equalize the lead or make it unequal, as is often done with large and heavy connections. "Midway" is only a com-

parative expression, for the eccentrics are not midway between horizontal and vertical lines, but are advanced slightly to make up for the lap and lead.

It will be readily seen that it is a very simple task to adjust a link-motion by this method. The idea of pinching or barring a heavily connected engine with the piston in, and all stuffing-boxes packed, is absurd, but it is very frequently done by persons who should have thought a little further.

To sum up the whole operation of setting an eccentric on a shaft: Get the eccentric-rod of the proper length first; then set the eccentric with the longest part at quarter-stroke, and opposite the crank-pin when the main crank is on the centre; turn the shaft once to equalize the lead, and make the eccentric-wheel fast on the shaft. If the lap and lead allowances have been correctly made, this will bring the eccentric where it should be.

Machine Finish.

The appearance of mechanical details is greatly improved by the character or the finish done upon them. Finishing, so-called, is not merely to surface polish the details, but it comprises, also, the workmanship upon them in fitting one part to another. Slovenly workmen pay no attention to sharp corners, true surfaces before polishing, and square corners where they are meant to be square,

or round corners where they are meant to be round, and the result is that, even if the work is well designed otherwise, it has the appearance of a second-class job. Nothing can be slighted in the way of fitting, if it is only upon a small model, if an amateur expects credit for or satisfaction in his productions.

As regards surface polish there are many kinds of this, each of which has certain values. The simplest of them is to produce a true surface by files or scrapers without scratches or hollow places in it, and then polish with emery cloth of different degrees of fineness. This is much easier said than done to those who have had no experience, and about the first trouble an amateur experiences, after he is able to produce a reasonably true surface, is in keeping scratches out of his work. Scratches are caused by the files "pinning-up" as it is termed; that is, minute particles of metal getting caught in the teeth of the file and tearing the surface of the work. This is very apt to occur with fine files, and workmen can tell in a moment, with one rub of a file, whether this has happened or not; the file should be cleaned at once, and chalk rubbed over it, so that the filings will have no hold on the file. On wrought metal or steel the file should be greased slightly, and cleaned with a wire brush occasionally, to keep it cutting. When "draw-filing" a finish be careful to keep the line of filing and subsequent polishing exactly true with the length of the work, not helter-skelter,

all over it in any direction. For a glazed finish use old crocus cloth, which is greasy, and rub it on hard and long; this will give a brilliant polish when finally cleaned with chalk and dry rouge, but it will also bring out every scratch in the job by filling it up with dirt; so that, unless the amateur wishes to have the reproach of "high polish and deep scratches" applied to him, he should avoid crocus cloth and use flour emery paper for the last touches.

Oil–stone Finish.

This consists in bringing the work to a true plane by filing and scraping, and then going carefully over it in detail with a small oil-stone slip. This finish should be mottled and waved in appearance at the will or taste of the workman, but it is slow work and should be done upon small parts only.

Acid Finish.

A dead-bright surface can be given to machine parts by immersing them a few moments in strong nitric acid, and then immediately plunging the parts into strong soda water, and carefully washing them in clear water until it is certain that the acid has been removed. The effect of the job is much enhanced by using a scratch brush on them, run at high speed in the lathe. This finish is not recommended for parts that have to be handled much, for it will turn black quickly unless pro-

tected from the air by shellac — varnish, or transparent collodion.

Scraped Finish.

This consists in bringing the work to a true plane, and then mottling the surface with patches scraped here and there, but alternating, with some approach to regularity. It is chiefly effective upon cast-iron surfaces of some area. A finish of more or less ornamental appearance, called worm-finish can be imparted by putting a pine plug in the chuck and turning it true on the end and face. Charge the end with flour emery and oil, and then place the work against the back spindle and screw up on it, moving the work in straight lines or curves as desired. This gives a very bright finish of peculiar aspect, and is frequently used upon watch movements.

Soldering and Brazing.

A knowledge of this work is very convenient to machinists, but difficulty is experienced sometimes in making a good job. This is because the surfaces to be joined and the agent used in doing the work, the soldering-iron, so-called, are not clean. The surfaces of the work must be absolutely bright, without a trace of tarnish upon them, or the solder will not take. Sand-paper will, in a majority of cases, answer to clean the parts, but it is sometimes necessary to use files or scrapers; but it must be borne in mind that the solder

will not adhere unless there is a clean surface present. For tin the solder will adhere if it is clean, with rosin only as a flux; but for brass it is necessary to use a solution called muriate of zinc. This is merely clean zinc dissolved in muriatic acid; put zinc cuttings and muriatic acid in a bottle, and when it will not bubble or give off fumes any more the acid is spent, and is then saturated. Pour it carefully into another clean bottle so that no dregs of zinc enter, and fill it up with ¼ of its bulk of soft water; wet the parts with this and heat them on a hot plate; then rub a stick of tin over them until they are coated with it, and solder in the usual way with a soldering-iron, or bind them together with wire, and sweat them together as it is called, by heating on a hot plate until the solder flows. This solder holds very strongly, and pieces of irregular shape which could not be otherwise held may be soldered onto the face-plate and machined off. Iron, cast or wrought, can be tinned by filing it bright or putting it in acid, if small, and then heating it on a plate over the fire so that no smoke or gas reaches it, and then covering the surface with sal-ammoniac; rub tin all over until it melts, and solder in the usual way. Common solder is 2 parts tin and 1 part lead by weight. Fine brass jobs which cannot be reached by an iron can be joined by dipping the surfaces in a strong solution of sal-ammoniac, putting a strip of tin foil between them, and binding them with wire; heat just enough to flow the tin.

Silver solder, so-called, is 34 parts weight of silver coin and 5 copper. Melt in a clean crucible, and when partly cooled add 4 parts zinc, stirring vigorously. If the metal is too hot when the zinc is put in it will all burn out. Drop or pellet solder is made by taking common solder and pouring it into cold water, having the solder only hot enough to run easily.

Brazing.

This process differs from soldering in the nature of the agent employed to hold the parts to be joined. Brazing is accomplished by melting brass filings applied directly on the seam and fused in it by holding the work over a fire. It requires considerable practice to do it successfully, and is hardly within the pale of amateur work; but if any one desires to try it, let them scrape the seam surfaces bright, and apply sal-ammoniac and brass filings directly to the seam with a small spoon made of a copper strip. The work must be moved to and fro over a charcoal fire, and when the copper approaches red-heat, the solder or brass will flow into the seam. This reads very simply, but whoever undertakes it for the first time will find that it is not so easy as it reads.

CHAPTER XII.

BOILERS.

A BOILER which will merely hold hot water and stand pressure up to 10 pounds can be made of tin soldered together like a teakettle, but such a boiler is not worth the time spent upon it. It is merely a makeshift, and unworthy of any one who aspires to be more than a tinker. A boiler to be of any use must be of some considerable dimensions and thickness of plate; it must have a good fire-box and ample heating surface for the work it has to do, and it must be properly proportioned as well for the fuel used.

If it is desired merely to *run* an engine to see it in operation under low pressure, the quickest made, cheapest, and most compact form of boiler is the common cylinder boiler, used with charcoal fuel, or arranged for a gasoline burner, such as is now sold for melting lead in pots by plumbers. This is a cheap fuel, but it is not a particularly safe one, for gasoline is treacherous stuff, and brooks no careless hands or heads about it.

A copper boiler, 4 inches diameter by $\frac{1}{16}$ thick and 12 inches long, will *drive* (that is run) an engine with 1 inch diameter of cylinder by $1\frac{1}{2}$-inch

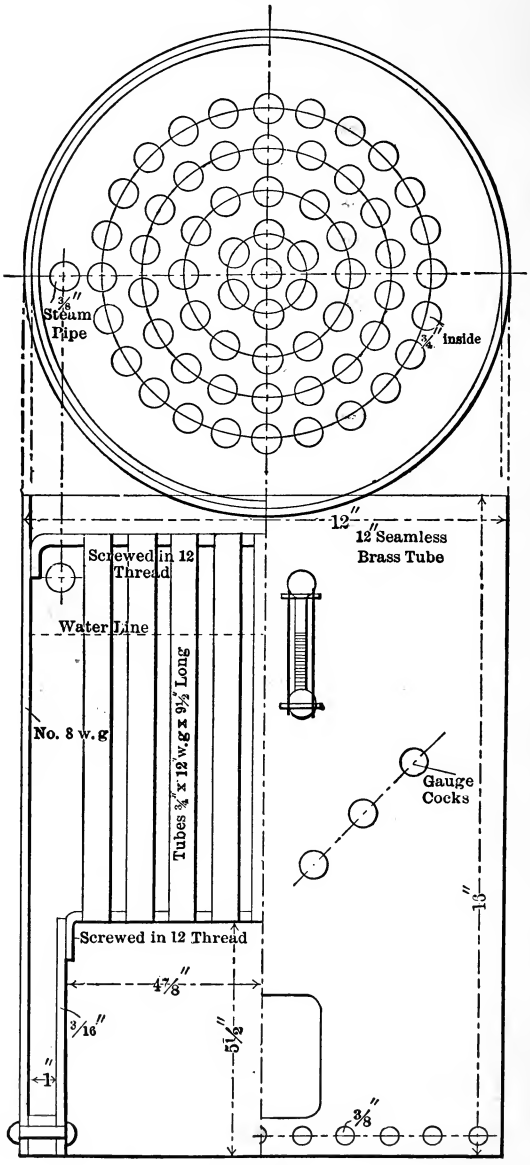

1⅜" Steam Pipe
¾" inside
12"
12" Seamless Brass Tube
Screwed in 12 Thread
Water Line
No. 8 w.g
Tubes ¾" x 12 w.g x 9½" Long
Gauge Cocks
13"
Screwed in 12 Thread
4⅞"
3/16"
5½"
1"
⅜"

Fig. 28.

stroke of piston all day long at 1,000 revolutions per minute, and maintain a pressure of 50 pounds if properly arranged as to the heating sur-

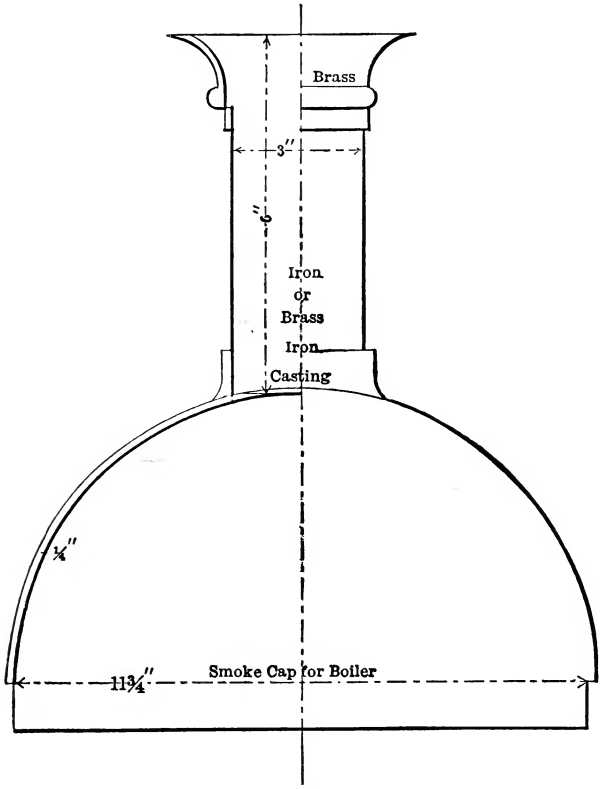


Fig. 28. Boiler Cap.

face; but the water must be constantly renewed, and to do this some sort of a feeding apparatus must be employed; the simplest to make is a

common plunger-pump with two valves, suction, and delivery, but a much better and more convenient form of boiler for amateurs is the vertical tubular boiler, as shown in the diagrams.

This, as will be seen, is easily made by any fairly good workman, and has no rivets to bother by leaking in inaccessible places, the only ones being on the bottom where they can easily be put in.

The dimensions are given in the diagrams; the total heating surface in the tubes is 7 square feet, which with gasoline fuel should give very nearly 1-horse-power. If a seamless brass tube cannot be easily had of the size given, a coppersmith will make a copper-tube brazed which is very nearly as strong, or, at all events, strong enough for a working pressure of 150 pounds.

The rule to find the bursting pressure of any cylindrical shell or tube is, to multiply the thickness of the metal in parts of an inch by $\frac{1}{4}$ of the tensile strength, and divide by half the diameter of the tube.

For example: the tensile strength of copper is (brazed) 30,000 pounds per square inch; $\frac{1}{4}$th of this is 7,500 pounds. The copper is $\frac{1}{8}$th thick (decimal .125). So 7,500 $\times$ by .125 = 937.5; dividing this by half the diameter of the tube, 6 inches, gives us 156 pounds working pressure, which is just $\frac{1}{2}$ of the bursting pressure or actual strength of the tube.

The heads are cast-brass, or may be of copper flanged, but brass is easier to cut a thread on than

copper, and must be screwed in tight. It will be seen that this is a pretty good job for an amateur's lathe, which would hardly swing it, and if preferred the tube sheets can be riveted in with $\frac{3}{8}$ copper rivets spaced $\frac{3}{4}$ inch between centres.

The edges of the tube sheets must be caulked tightly after riveting, and a rivet-set used on the outside heads to make a neat finish. The tubes are $\frac{3}{4}$ inside, because they are to be expanded in, and that is the smallest expander to be had; they will be absolutely tight when rolled, and need not be riveted over on the ends; no steam pressure can draw them out. The dome on top for the smoke-stack will require a pattern made for it if it is intended to have a neat appearance. The gauge-cocks can be bought in brass-goods stores, they are called "$\frac{1}{8}$th air-valves," and are very small, neatly-finished valves, nickle-plated, costing 15 cents apiece. The feed-pipe enters at the bottom, and will require a check-valve close to the shell. The steam-pipe emerges where marked, and branches can be taken from it to carry the steam-gauge, safety-valve, and whistle if required.

In drilling the holes for the tubes in the tube-sheets be careful to get exactly the same number of tubes in each row of both sheets; if this is not done there will be an odd hole which will have to be closed by a plug.

Made in brass or copper this boiler will cost considerable, and it can be made of steel just as well, with steel tubes; but these last are apt to

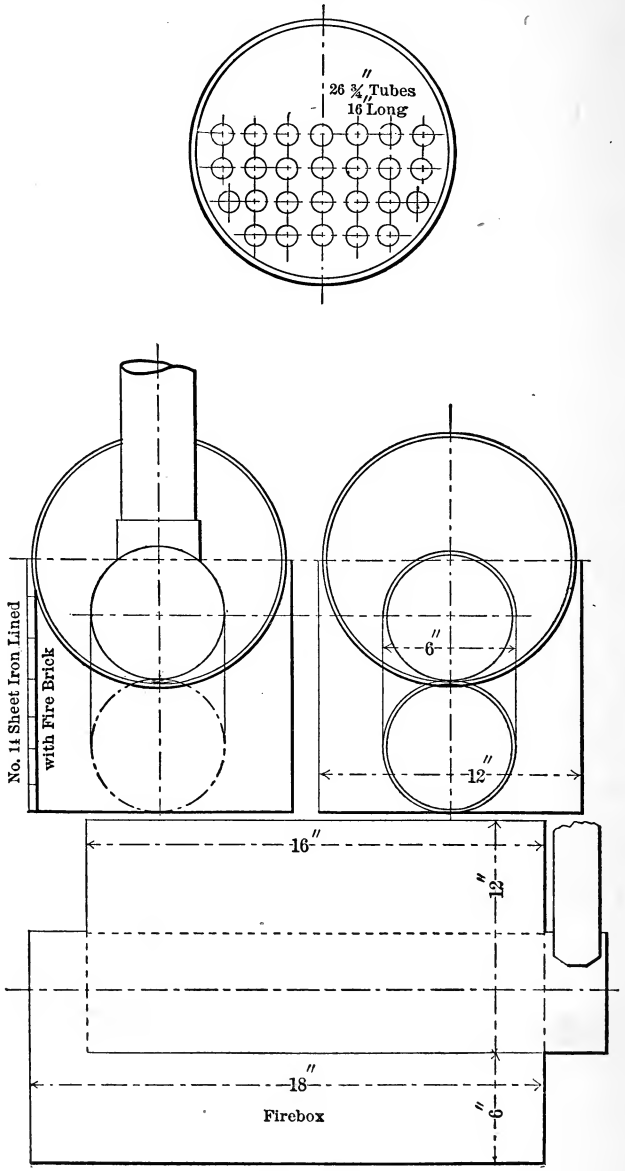

26 ¾" Tubes
16" Long
No. 14 Sheet Iron Lined
with Fire Brick
6"
12"
16"
12"
18"
Firebox
6"

Fig. 30.

corrode very quickly, and it is better to use brass tubes. Any small boiler-shop will make a 12-inch steel tube by 16 inches long, by No. 10 wire gauge, for a very moderate sum, and the heads can be flanged, also, in steel. With this material such a boiler can be made very reasonably.

At 150 pounds pressure and with gasoline fuel, — or, if preferred, charcoal or coke used with a blast, such as the engine exhausting into the stack, — an engine 1½-inch cylinder by 3-inch stroke, running at 1,000 revolutions per minute should deliver 1 horse-power, ample to drive all the tools in an amateur's shop, or a model yacht 8 or 10 feet long, by 18 inches beam.

A horizontal boiler can be made which will do good work by following the diagram Fig. 30. This boiler will require a setting which may be of sheet-iron, $\frac{1}{16}$ thick, and a breeching, as it is called, to go over the internal flue where it emerges from the head. This is a cheap boiler to make also, as it can be wholly brazed together without a rivet in it, and it will carry a high pressure; but it will not do the work that the vertical boiler will, because it has very little heating surface for its dimensions. These last are, we will say, 16 inches long by 12 inches diameter, the same as the vertical boiler; but the effective heating surface is the bottom and the internal flue, altogether only 408 square inches, or a little less than 3 square feet. This would amount to nothing at all for power purposes, and would only be useful

as a toy. If, however, we arrange the tubes as in the upper figure we can get $9\frac{1}{2}$ square feet heating surface, or about 1 horse-power.

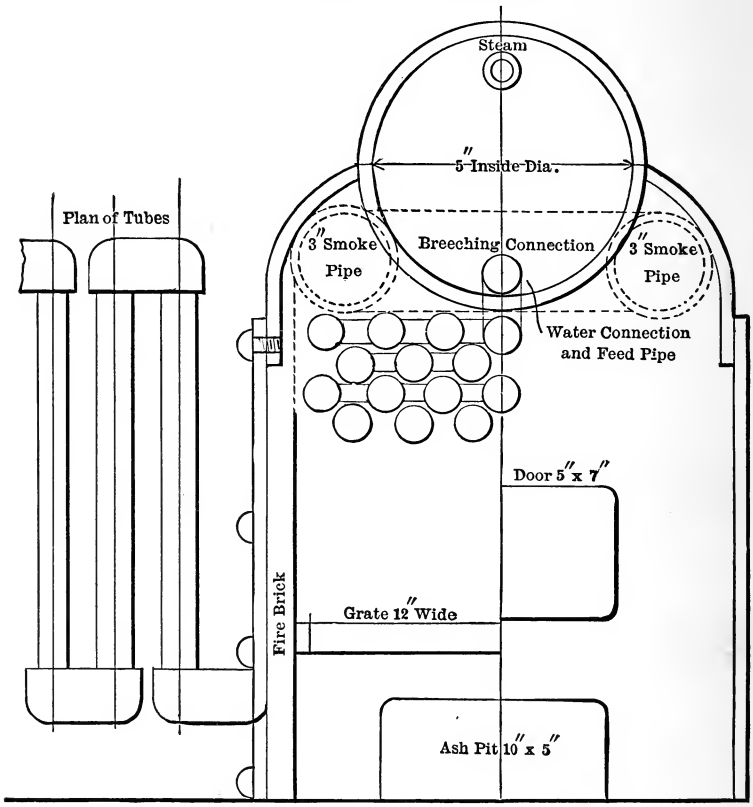


Fig. 31.

A horizontal water-tube boiler is another affair, and, in the same space as the horizontal boiler just described, will give a great deal of power.

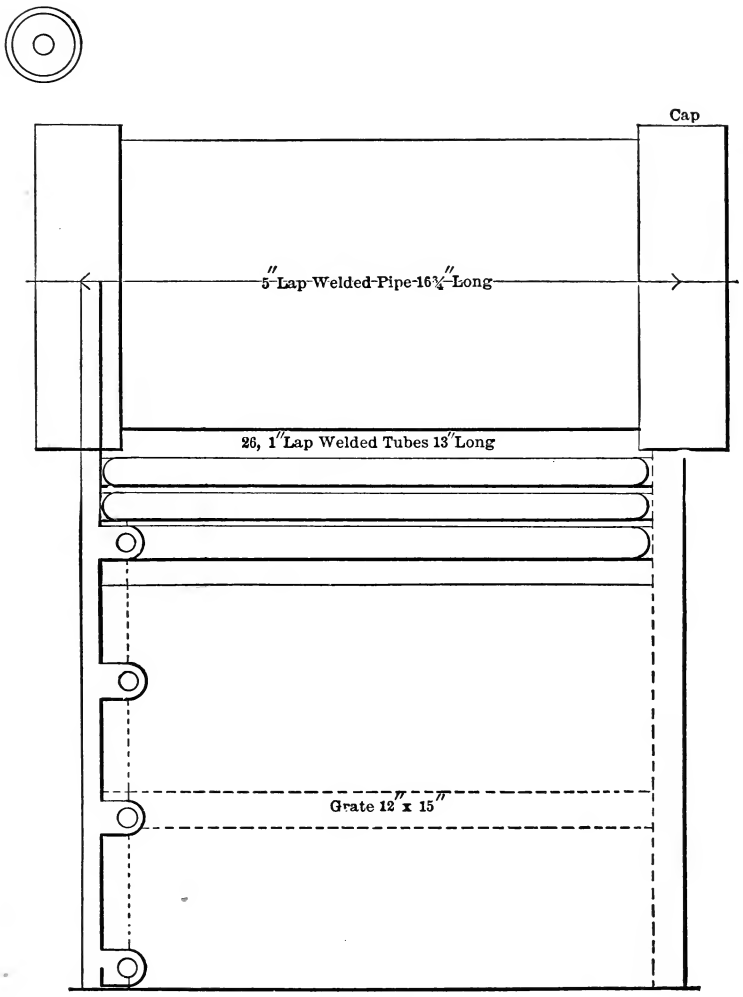

Cap
5″ Lap Welded Pipe 16¾″ Long
26, 1″ Lap Welded Tubes 13″ Long
Grate 12″ x 15″

Fig. 32.

There is another advantage in it — that gasoline or oil fuel can be used readily. Either of these fuels are far better than coal for small boilers. The trouble with it is that it does not burn easily in a confined space like a small fire-box; moreover it is very dirty, and requires constant superversion. With oil there is no trouble or annoyance beyond the odor. With gasoline, as before explained, great care must be taken to have not the slightest leak of the fluid externally, or there will be a very dangerous explosion. The water-tube boiler is not at all difficult to make, and affords an interesting study as to the action. It can be either of the horizontal inclined type or the vertically inclined type, as desired; an amateur can easily make the horizontal water-tube type. As will be seen by the engraving the generating surfaces comprise a series of tubes directly over the fire connected with the steam-drum on top. The feed-pipe enters this at the bottom and the steam-pipe issues from the top of the dome or drum. This last is made of a section of lap-welded wrought-iron pipe, and the heads are the caps which go on the same and can be found in any engineer's store. The tubes are lap-welded also, and the connections at the end are the malleable iron return-bends also kept in stock. The diagram shows how the series (3) are connected to each other, each series being also connected at the sides by running one of the return-bends at right angles, or turned down

toward the bottom of the boiler, both sides and ends (4 in all) of the series must be connected, for the steam in the lower series has to pass through them on the way to the drum. For a large boiler this would not be a good plan, but in this size it will answer. This boiler has 15 square feet of heating surface, and $1\frac{1}{4}$ square feet of grate surface, and will easily deliver $1\frac{1}{2}$ horse-power. It will burn any kind of fuel, wood, coal, or coke, and will stand 500 pounds per square inch. This is the advantage that water-tube boilers have over fire-tube boilers; they can carry higher pressure, and are much lighter for equal powers.

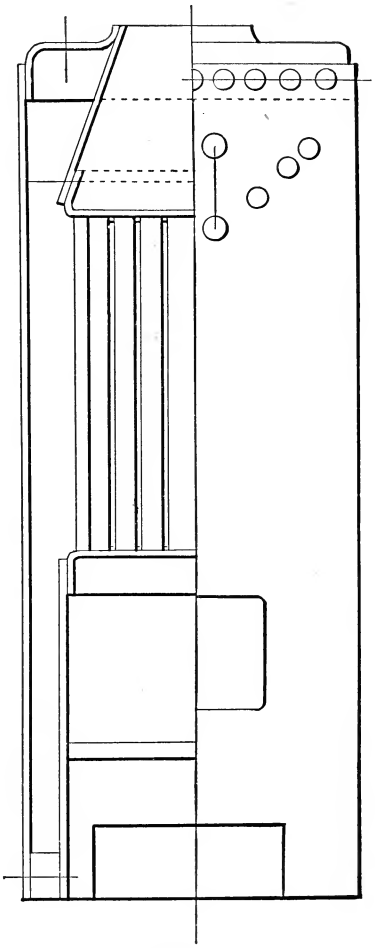


Fig. 33.

It must be borne in mind, if this boiler is to carry high pressures, that all screwed fit-

tings must be thoroughly leaded — that is, covered with red-lead putty (made of white lead and red lead to a stiff dough) before being made up; and that no pipe or union must be screwed together and then taken apart; if this is done the joints will leak, for they are stretched much larger than the original size.

The boiler thus far described will answer for all purposes amateurs are likely to have, and, while some of the parts cannot be made by them for want of facilities, they are not expensive to have made by workmen. They are in no sense of the word toys, to be run with alcohol lamps, but will burn coal, wood, or oil fuel when properly managed. Between merely driving an engine and running it for power purposes, there is a great difference, and that is where many persons fail to get power out of small engines. They have no boilers to run them. Commercial engines for power purposes can be had in market with cylinders of only 2 inches diameter, by 3 inches stroke, but they require 150 pounds of steam.

Vertical submerged tubular boilers are in use in some parts of the country as shown (Fig. 33), but it is not a desirable boiler for amateurs to make, on account of the difficulty in getting the tubes in the upper head, and making the whole boiler tight. The launch engine $3'' \times 4''$ will require a boiler of 30 square feet heating surface, and is wholly beyond the facilities and experience of amateurs to construct.

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